

SHOUT **IT**
SHARE

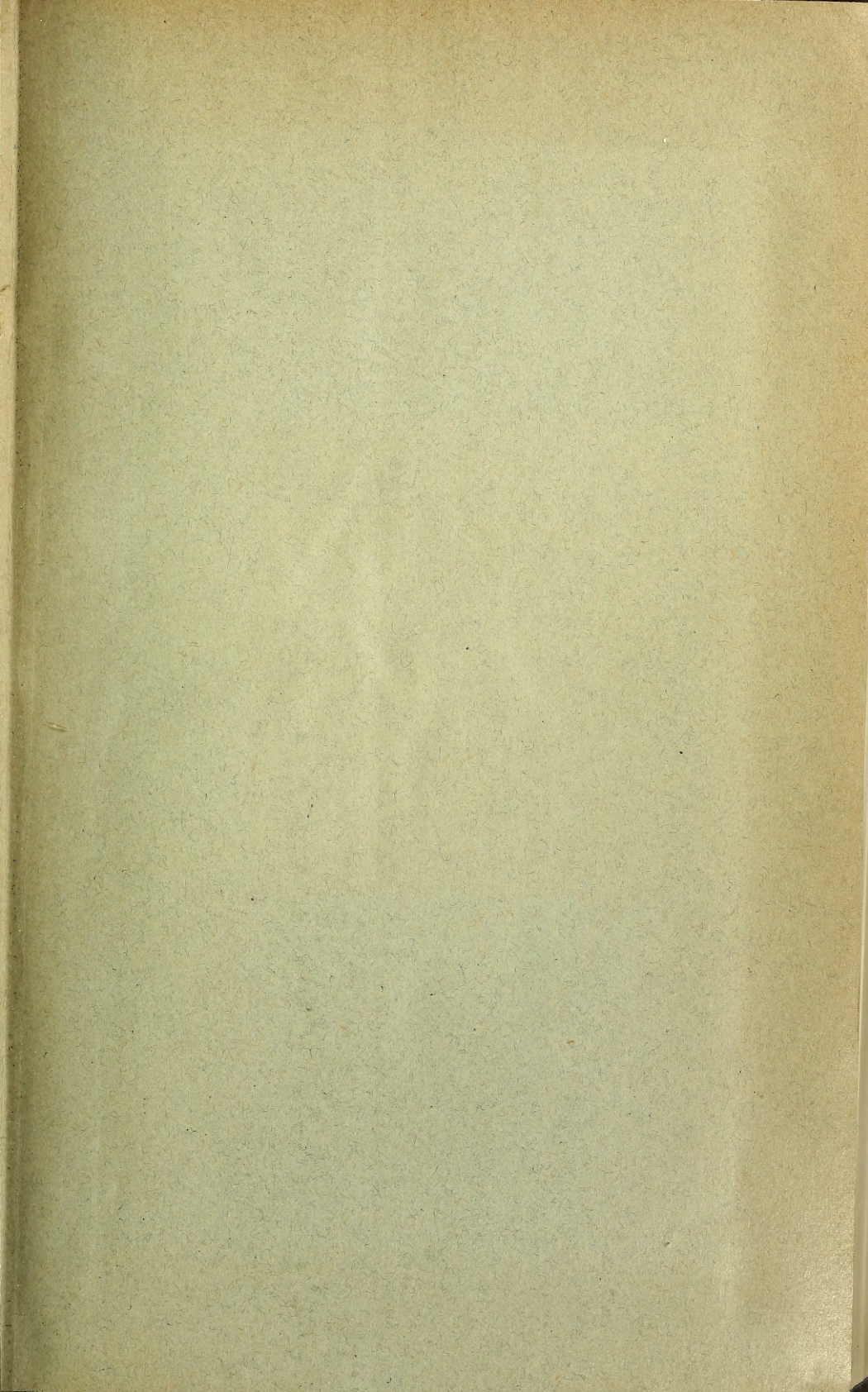


63 06 (73)

FOR THE PEOPLE
FOR EDUCATION
FOR SCIENCE

LIBRARY
OF
THE AMERICAN MUSEUM
OF
NATURAL HISTORY

Bound at
A. M. N. H.
1924





U. S. DEPARTMENT OF AGRICULTURE.

LIBRARY
OF THE
AMERICAN MUSEUM
OF NATURAL HISTORY

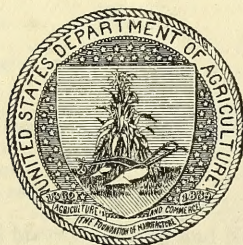
Department Bulletins

Nos. 1026-1050,

63.06(73)

WITH CONTENTS
AND INDEX.

Prepared in the Office of Editorial Work.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1923.

U. S. DEPARTMENT OF AGRICULTURE

LIBRARY
OF THE
AMERICAN MUSEUM
OF NATURAL HISTORY

Department Bulletin

Nos. 1026-1050

WITH CONTENTS
AND INDEX

24-95162 June 13

Prepared in the Office of Editorial Work



WASHINGTON
GOVERNMENT PRINTING OFFICE
1924

CONTENTS.

DEPARTMENT BULLETIN No. 1026.—IRRIGATION IN NORTHERN COLORADO:		Page.
Introduction.....		1
Cache la Poudre Valley.....		2
Meteorology.....		3
Soils.....		5
Water resources.....		6
Seepage return.....		10
Drainage conditions.....		12
Exchange of water.....		12
Water rights.....		13
Distribution from river.....		19
Duty of the river.....		24
Canal systems.....		26
Gross duty for canals.....		42
Farm irrigation.....		51
Reservoirs.....		69
Summary and conclusions.....		79
DEPARTMENT BULLETIN No. 1027.—POISONOUS METALS ON SPRAYED FRUITS AND VEGETABLES:		
Purpose of investigation.....		1
Results of previous investigations.....		1
Experimental work.....		16
Results of experimental work.....		18
Summary.....		58
Literature cited.....		58
DEPARTMENT BULLETIN No. 1028.—APANTELES MELANOSCELUS, AN IMPORTED PARASITE OF THE GIPSY MOTH:		
Introduction.....		1
Part I—Description and life history.....		2
History.....		2
Distribution in Europe.....		3
Description of species.....		3
Methods used in biological work.....		4
Life history.....		5
Seasonal history.....		11
Feeding of parasitized larvæ versus nonparasitized larvæ.....		12
Longevity experiments.....		12
Hosts of <i>A. melanoscelus</i>		12
Part II—Introduction and establishment.....		14
European work.....		14
Comparison of seasonal history in Sicily and New England.....		15
Abundance of <i>A. melanoscelus</i> in Sicily.....		15
Secondary parasitism in Sicily.....		16
Colonization in New England.....		16
Methods used to obtain material for colonization.....		18
Success of colonies and distribution of <i>A. melanoscelus</i>		21
Dispersion.....		22
Secondary parasitism.....		23
The value of <i>A. melanoscelus</i> as a gipsy-moth parasite.....		23
Abundance of <i>A. melanoscelus</i> in New England.....		24
Conclusion.....		25

DEPARTMENT BULLETIN No. 1029.—SEED TREATMENT AND RAINFALL IN RELATION TO THE CONTROL OF CABBAGE BLACKLEG:

	Page.
Introduction.....	1
Effect of fungicidal treatment in the laboratory upon seed and the seed-borne fungus.....	3
Heat and desiccation.....	5
Formaldehyde solution.....	7
Hot water.....	9
Mercuric-chlorid solution.....	10
Summary of laboratory seed-treatment experiments.....	12
Field trials with treated seeds.....	13
Development of the disease in seed bed.....	13
Relation of rainfall to the development of the disease.....	14
Importance of spread in the seed bed as compared with dissemination in the field.....	17
Seed-bed trials at Madison, Wis., in 1919.....	18
Results with treated seeds in commercial fields.....	20
Importance of disease-free seeds.....	23
Summary.....	25
Literature cited.....	27

DEPARTMENT BULLETIN No. 1030.—MEADE COTTON, AN UPLAND LONG-STAPLE VARIETY REPLACING SEA ISLAND:

Need of replacing sea-island cotton.....	1
Decline of the sea-island industry.....	2
Value of Meade cotton as a substitute for sea-island demonstrated.....	2
Origin of the Meade variety.....	3
Description of the variety.....	4
Meade cotton adapted to sea-island conditions.....	4
Increasing seed supplies in 1918.....	6
Experiments with Meade cotton in 1917 and 1918.....	9
Work with Meade cotton in 1919.....	10
Extending the cultivation of Meade cotton in 1920.....	11
Production of Meade cotton in 1920.....	14
Cultivation of Meade cotton.....	15
Closer spacing with Meade cotton.....	16
Problem of seed supply of Meade cotton.....	18
Selection necessary to maintain uniformity.....	18
Spinning tests of Meade cotton.....	20
Conclusions.....	22
Literature cited.....	24

DEPARTMENT BULLETIN No. 1031.—RANGE AND CATTLE MANAGEMENT DURING DROUGHT:

The problem of drought and cattle production.....	1
Jornada Range Reserve.....	4
Types of vegetation.....	5
Use of the area prior to reservation.....	10
Recurrence of drought.....	11
Variation in forage production.....	18
Variation due to drought.....	19
Variation due to grazing.....	25
Forage-production conclusions.....	33
Grazing capacity.....	34
Yearlong or winter range.....	35
Summer range.....	40
Adjustments necessary in cattle management.....	41
Southern New Mexico a cattle-breeding section.....	42
Breeding herd should be limited to grazing capacity of the range during drought.....	43
Surplus stock should vary with range forage production and with the market.....	46
Range management to obtain maximum forage production and proper use.....	49

DEPARTMENT BULLETIN No. 1031.—RANGE AND CATTLE MANAGEMENT DURING DROUGHT—Continued.

	Page.
Improvements necessary to meet increase in cost of cattle production.....	53
Improvement in grade of stock.....	54
Increasing calf crop.....	58
Decreasing losses of cattle.....	65
Increasing growth of young stock.....	77
Summary.....	79
List of publications relating to this subject.....	82

DEPARTMENT BULLETIN No. 1032.—THE BLACKHEAD FIREWORM OF CRANBERRY, ON THE PACIFIC COAST:

Introduction.....	1
Importance of the blackhead fireworm.....	2
The cranberry industry on the Pacific coast.....	2
Features of bog management.....	3
Phenology of the cranberry on the Pacific coast.....	3
Introduction of the blackhead fireworm into the Northwest.....	4
Distribution.....	5
Food plants.....	5
Destructiveness.....	5
Number of generations.....	6
Description of stages and habits.....	7
Seasonal history.....	19
Natural enemies.....	20
Control experiments.....	22
Recommendations for control.....	34
Summary and conclusions.....	37
Systematic description of <i>Rhopobota naevana</i> Hubner.....	42
Explanation of plates.....	45

DEPARTMENT BULLETIN No. 1033.—DIGESTIBILITY OF COD-LIVER, JAVA-ALMOND, TEA-SEED, AND WATERMELON-SEED OILS, DEER FAT, AND SOME BLENDED HYDROGENATED FATS:

Purpose of investigations.....	1
Experimental method.....	2
Experiments.....	3
Cod-liver oil.....	3
Java-almond oil.....	5
Tea-seed oil.....	6
Watermelon-seed oil.....	7
Deer fat.....	8
Blended hydrogenated fats.....	9
Summary of results.....	15

DEPARTMENT BULLETIN No. 1034.—FARM MANAGEMENT AND FARM ORGANIZATION IN SUMTER COUNTY, GA.:

Introduction.....	1
Summary of results.....	3
Area studied.....	5
Utilization of the land.....	7
Farm organization and business analysis of farms.....	8
Size of farms.....	10
Crops grown and yields.....	11
Distribution of farm receipts.....	21
Distribution of expenses.....	25
Capital.....	28
Farm earnings.....	31
Family farms.....	38
Choice of enterprises.....	43
Diversity.....	46
Factors affecting the successful operation of these farms.....	50
Bearing of farm organization on cost of producing cotton.....	58
Appendix.....	72

DEPARTMENT BULLETIN No. 1035.—THE RED SPIDER ON THE AVOCADO:		Page.
Introduction.....		1
Economic importance.....		1
Nature of injury to foliage.....		2
Food plants and distribution.....		2
Description and habits.....		4
Biological data.....		7
Predatory enemies.....		9
Spraying experiments.....		11
Spray rod versus spray gun.....		13
Cultural methods in the grove.....		14
Recommendations.....		15
DEPARTMENT BULLETIN No. 1036.—COAL-TAR AND WATER-GAS TAR CREOSOTES—THEIR PROPERTIES AND METHODS OF TESTING:		
Foreword.....		1
Part I. Tars and the production of creosotes from tars.....		3
Chapter I. Introduction and definitions.....		3
Chapter II. Composition of tars and methods of manufacture.....		7
Chapter III. Production of creosote from tars.....		19
Part II. Experimental comparison of authentic specimens of creosote.....		23
Chapter I. Collecting and testing the specimens of creosote.....		23
Chapter II. Determining certain conditions for the tests.....		35
Chapter III. Results of the tests.....		38
Chapter IV. Comparison of the properties of authentic coal-tar creosotes with those of authentic water-gas-tar creosotes.....		44
Part III. Properties of creosotes.....		47
Chapter I. Composition and chemical properties of coal-tar creosotes.....		47
Chapter II. Physical properties of coal-tar creosotes.....		50
Chapter III. Toxic properties of coal-tar creosotes.....		66
Chapter IV. Composition and properties of water-gas-tar creosotes.....		73
Chapter V. Comparison of the properties of commercial coal-tar creosotes and commercial water-gas-tar creosotes.....		77
Chapter VI. Tar-creosote solutions.....		79
Chapter VII. A theory of the mechanism of the protection of wood by oil solutions.....		84
Part IV. Methods of testing creosotes and official specifications for creosote.....		87
Chapter I. Practical methods of testing creosotes.....		87
Chapter II. Specifications now in force by various associations.....		103
Appendix.....		106
Bibliography.....		112
DEPARTMENT BULLETIN No. 1037.—THE CONTROL OF SAP-STAIN, MOLD, AND INCIPIENT DECAY IN GREEN WOOD, WITH SPECIAL REFERENCE TO VEHICLE STOCK:		
Introduction.....		1
Sap-stain.....		3
Other fungous organisms causing surface discolorations in green timber.....		12
Factors which favor the growth of sap-stain and mold fungi.....		14
Durability of stained or molded wood.....		17
Losses due to sap-stain or mold.....		18
Control measures.....		21
Summary.....		50
Literature cited.....		52
DEPARTMENT BULLETIN No. 1038.—PECAN ROSETTE—ITS HISTOLOGY, CYTOLOGY, AND RELATION TO OTHER CHLOROTIC DISEASES:		
Types of chlorotic plant diseases.....		1
Chloroses due to soil or atmospheric conditions.....		2
Infectious chloroses.....		6
Studies of pecan rosette.....		13
Results of previous work.....		13
External signs of rosette.....		17
Histological and cytological studies.....		19
Subsidiary experiments.....		30
Probable nature of pecan rosette.....		31
Summary.....		36
Literature cited.....		37

DEPARTMENT BULLETIN No. 1039.—EXPERIMENTS WITH CEREALS ON THE
BELLE FOURCHE EXPERIMENT FARM, NEWELL, S. DAK.:

Page.

The cereal experiments.....	1
Description of the field station.....	2
Location.....	2
History of the region.....	3
Soil.....	4
Native vegetation.....	4
Climatic conditions.....	5
Experimental methods.....	11
Preparation of the land.....	11
Plat experiments.....	11
Nursery experiments.....	12
Experiments on dry land.....	13
Experiments with wheat.....	13
Experiments with oats.....	27
Experiments with barley.....	32
Experiments with minor cereals.....	36
Comparison of grain crops.....	41
Experiments with flax.....	42
Experiments on irrigated land.....	45
Experiments with wheat.....	46
Experiments with oats.....	52
Experiments with barley.....	56
Experiments with minor cereals.....	59
Experiments with grain mixtures.....	62
Comparison of grain crops.....	64
Experiments with flax.....	65
Tillage experiments.....	69
Summary.....	70

DEPARTMENT BULLETIN No. 1040.—CONTROL OF THE CITROPHILUS MEALYBUG:

Introduction.....	1
History and distribution.....	2
Economic importance.....	3
Host plants.....	4
Description and life history.....	4
Seasonal history.....	6
Relation to Argentine ant.....	8
Comprehensive demonstrations of control.....	8
Natural enemies.....	19
Summary.....	20

DEPARTMENT BULLETIN No. 1041.—A STUDY OF SWEET-POTATO VARIETIES,
WITH SPECIAL REFERENCE TO THEIR CANNING QUALITY:

Introduction.....	1
Chemical composition of sweet potatoes.....	3
Experimental canning tests.....	6
Discoloration.....	13
Heat penetration and sterilization.....	16
Consistency.....	16
Varieties and strains of sweet potatoes used in these tests.....	23
Summary.....	30
Literature cited.....	33

DEPARTMENT BULLETIN No. 1042.—EFFECT OF WINTER RATIONS ON PASTURE
GAINS OF CALVES:

Outline of the experimental work.....	1
The region and its problems.....	2
Objects and plan of the work.....	3
Kind of calves used.....	3
Feeds used.....	3
Character of pasture.....	5
Method of feeding and handling the calves.....	5
I. Winter rations and their influence on pasture gains of calves.....	6
Quantity of feed consumed.....	6
Gains during winter.....	7
Gains during summer.....	8

DEPARTMENT BULLETIN No. 1042.—EFFECT OF WINTER RATIONS ON PASTURE
GAINS OF CALVES—Continued.

	Page.
Gains for winter and summer.....	8
Diagrams of gains and losses.....	9
Summary of feeding.....	11
II. Cost of rations for wintering calves.....	11
Cost per pound of gain.....	13
Summary of costs.....	15

DEPARTMENT BULLETIN No. 1043.—CROP INSURANCE—RISKS, LOSSES, AND
PRINCIPLES OF PROTECTION:

The farmer's "independence".....	1
Meaning of "loss" or "damage" in connection with growing crops.....	2
Quantitative importance of annual damage to farm crops.....	5
Elimination or reduction of risk.....	13
Self-insurance.....	13
Insurance by contract.....	16
Principles of crop insurance.....	18
Summary.....	26

DEPARTMENT BULLETIN No. 1044.—SELF-SERVICE IN THE RETAILING OF FOOD
PRODUCTS:

Introduction.....	1
Self-service.....	2
Advantages and disadvantages of self-service.....	4
Problems in self-service.....	14
Handling perishable farm products.....	35
Accounting.....	39
Summary of investigations.....	49

DEPARTMENT BULLETIN No. 1045.—THE SUNFLOWER AS A SILAGE CROP:

Early history of the sunflower.....	1
Present distribution.....	2
Cultivation in the United States.....	2
Areas suited to the production of sunflowers.....	4
Value of sunflowers in the semiarid regions.....	5
Soil relations and effect on the following crop.....	7
Varieties.....	7
Growing sunflowers for silage.....	9
Date of seeding.....	10
Method and rate of seeding.....	10
Cultivation and irrigation.....	11
Harvesting methods.....	12
Time to cut sunflowers.....	13
Filling the silo.....	15
Yields of silage.....	17
Feeding value of sunflower silage.....	19
Composition and digestibility.....	20
Palatability.....	21
Color, texture, and odor.....	22
Acidity of the silage.....	23
Results with dairy cattle.....	23
Feeding tests with beef cattle.....	26
Use of sunflower silage in feeding sheep.....	27
Feeding sunflower silage to hogs.....	29
Sunflowers as a soiling crop.....	29
Diseases of sunflowers.....	30
Insects attacking sunflowers.....	31
Literature cited.....	31

DEPARTMENT BULLETIN No. 1046.—RUST RESISTANCE IN WINTER-WHEAT
VARIETIES:

Scope of the investigation.....	1
Review of the literature.....	2
Nursery experiments.....	4
Greenhouse experiments.....	14
Comparison of nursery and greenhouse results.....	23
Evidence of specific rust resistance.....	24

DEPARTMENT BULLETIN No. 1046.—RUST RESISTANCE IN WINTER-WHEAT VARIETIES—Continued.

	Page.
Agronomic value of Kanred wheat.....	26
Summary.....	27
Literature cited.....	30

DEPARTMENT BULLETIN No. 1047.—FARM MORTGAGE LOANS BY BANKS, INSURANCE COMPANIES, AND OTHER AGENCIES:

Need of more complete data.....	1
Nature and comparability of data.....	2
Loans by life insurance companies.....	4
Loans by Federal Land Bank System.....	4
Loans from State funds or agencies.....	5
Loans by farm mortgage bankers.....	5
Other sources.....	5
Basis of figures on loans by banks.....	6
First and second mortgage loans by banks.....	9
Interest rates on farm mortgage loans.....	10
Term of loan and method of repayment.....	21
Conclusion.....	21

DEPARTMENT BULLETIN No. 1048.—BANK LOANS TO FARMERS ON PERSONAL AND COLLATERAL SECURITY:

Amount of personal and collateral bank loans to farmers.....	2
The estimated amount of personal and collateral loans to farmers.....	3
Seasonal fluctuation in personal and collateral loans to farmers.....	4
Rates of interest.....	6
Minimum balance requirements for bank loans to farmers on personal and collateral security.....	17
Interest collections in advance.....	20
Nature of security for farmers' personal and collateral loans.....	20
Term of loan.....	22
Conclusion.....	25

DEPARTMENT BULLETIN No. 1049.—GAME AS A NATIONAL RESOURCE:

Importance of game.....	1
Principal kinds of game in the United States.....	2
Value of game to the farmer.....	9
Value of game from the standpoint of health.....	10
Returns from license fees.....	11
Estimates of the value of game by State officials.....	12
Limitations on excessive hunting.....	15
Records of game killed.....	18
Enumerations of game.....	23
Methods of increasing game resources.....	25
Cost of maintaining game.....	44
Suggestions for making a survey of game resources.....	47

DEPARTMENT BULLETIN No. 1050.—THE IDENTIFICATION OF TRUE MAHOGANY, CERTAIN SO-CALLED MAHOGANIES, AND SOME COMMON SUBSTITUTES:

"Mahoganies".....	1
Key for the identification of true mahogany and mahoganylike woods.....	2
Description of species—	
True mahogany.....	4
Crabwood.....	6
Cedrela.....	7
Sapeli.....	8
"African mahogany".....	9
"Philippine mahogany".....	10
"Colombian mahogany".....	12
"Liberville mahogany".....	13
Birch.....	14
Red gum.....	15
"White mahogany".....	16
Glossary.....	16

INDEX.

	Bulletin No.	Page.
Accounting, self-service stores, management.....	1044	39-49
Adirondack Preserve, public hunting grounds.....	1049	29
<i>Agropyron</i> , spp, occurrence and importance in South Dakota.....	1039	4
Alberta, big game killed, 1907-1918.....	1049	23
Alfalfa—		
acreage under irrigation, Colorado, Cache la Poudre Valley, 1916-1917.....	1026	43
irrigation in Colorado, 1916, 1917.....	1026	62-63, 84
Almonds, Java—		
description.....	1033	5
digestibility of oil from.....	1033	5-6
Ammonium fluorid, use for timber preservation, experiments.....	1037	36-37
Ant, Argentine, relation to mealy bugs, and eradication experi- ments.....	1040	8-11, 20
Antelope, enumeration and value.....	1049	24, 25
Antiseptics, use—		
against sap-stain and mold in vehicle woods.....	1037	39, 51
in timber protection, experiments.....	1037	37-46
<i>Apanteles melanoscelus</i> —		
introduction, description, and life history.....	1028	2-14
parasite of the gipsy moth, bulletin by S. S. Crossman.....	1028	1-25
Appalachian Mountain region, wintering calves, effect of rations on pasture gains, bulletin by E. W. Sheets and R. H. Tuck- willer.....	1042	1-15
Apples, sprays, poisonous residue at picking time, investigations.....	1027	33-47, 49
Arid lands, ranges in Southwest, management during drought....	1031	11-79
Arsenic, spray, deposits on fruits and vegetables.....	1027	18-49
Avocado—		
injury by red spider.....	1035	2, 3, 8, 15
red spider, bulletin by G. F. Moznette.....	1035	1-15
spraying, apparatus and formulas for sprays.....	1035	11-13, 15
Bag limits, hunters in various States.....	1049	16, 18
Baits, poison, for Argentine ants.....	1040	9, 18
Banding, tree, for control of citrophilus mealybug.....	1040	11-13, 16
Banks—		
balance requirements in loans to farmers.....	1047	17-19
Federal land, relation to farm loans, conditions, etc.....	1047	4, 23
loans to farmers—		
balance requirements.....	1048	17-18, 25
on personal and collateral security, bulletin by V. N. Val- gren and Elmer Engelbert.....	1048	1-26
number replying to questionnaire, and farm loans reported, by divisions and States.....	1047	7
Barber formula, poison bait, use, and cost.....	1040	9
Barley—		
growing—		
on dry land, experiments in South Dakota.....	1039	32-35
under irrigation, experiments in South Dakota.....	1039	56-59
irrigation in Colorado, 1916, 1917.....	1026	65, 84
losses from specified causes in various localities, 1909-1918.....	1043	6, 8, 10
seeding rates and dates, dry-land and irrigation farming, South Dakota.....	1039	12, 35
BATEMAN, ERNEST, bulletin on "Coal-tar and water-gas-tar creos- otes: Their properties and methods of testing.....	1036	1-114

Beans—

	Bulletin No.	Page.
acreage under irrigation, Colorado, Cache la Poudre Valley, 1916, 1917.....	1026	43
irrigation in Colorado, 1916, 1917.....	1026	68, 84
velvet, crop area and uses in south Georgia.....	1034	12, 14-15
Beef cattle, feeding sunflower silage, experiments and results....	1045	26-27
Beetles, enemies of citrophilus mealybug.....	1040	19
Beans, sugar—		
acreage under irrigation, Colorado, Cache la Poudre Valley, 1916, 1917.....	1026	43
irrigation in 1916, 1917.....	1026	65-67, 84
Belle Fourche Experiment Farm, location, description, soil, and vegetation.....	1039	2-5, 70
Belmont sweet potatoes, canning value and description.....	1041	{ 8, 11, 24, 30
<i>Betula</i> spp., use as substitute mahogany, identification key and description.....	1050	1, 4, 14
Big-stem Jersey sweet potatoes, canning value and description...	1041	{ 8, 11, 27, 30
Birch, use as substitute mahogany, identification key, and description.....	1050	1, 4, 14
Birds—		
game, breeding for profit.....	1049	43-44
migratory, hunting regulations.....	1049	27-28
Bison, National Range, purchase and cost.....	1049	45
Blackhead fireworm of cranberry on Pacific coast, bulletin by H. K. Plank and Carl Heinrich.....	1032	1-46
<i>See also</i> Fireworm, blackhead.		
Blackleg—		
cabbage—		
control, relation of seed treatment and rainfall, bulletin by J. C. Walker.....	1029	1-27
development from cabbage seed.....	1029	1-3
control by vaccination.....	1031	74
Boll weevil—		
damage to sea-island cotton industry.....	1030	1-2
districts, value of Meade cotton.....	1030	1-3, 4-11
Bordeaux mixture, poisonous deposits on fruits and vegetables, investigations.....	1027	3-8
BORDON, A. D., and R. S. WOGLUM, bulletin on "Control of the citrophilus mealybug".....	1040	1-20
<i>Boswellia plaincana</i> , identification key and description.....	1050	4, 13
<i>Bouteloua oligostachya</i> , occurrence in South Dakota.....	1039	4
Breeding, <i>Apanteles melanoscelus</i> for gipsy-moth control, details..	1028	19-21
Buckwheat, growing—		
experiments, Belle Fourche Farm.....	1039	37, 72
experiments on irrigated land, Belle Fourche Farm.....	1039	61, 72
in South Dakota, experiments.....	1039	37, 61
Buffalo—		
enumeration, and value.....	1049	24, 25
grass, occurrence in South Dakota.....	1039	4
<i>Bulbils dactyloides</i> , occurrence in South Dakota.....	1039	4
Bulls, management on range.....	1031	62-63
Burlap, bands for trees.....	1040	11-13
Cabbage, blackleg control, relation of seed treatment and rainfall, bulletin by J. C. Walker.....	1029	1-27
<i>See also</i> Seed, cabbage.		
Cache la Poudre River, water diversion for irrigation.....	1026	19-23
California, Upland, control of Argentine ant in citrus orchard....	1040	11-19
Calves—		
feeding on ranges.....	1031	67-68, 79
gains on—		
pasture, effect of winter rations, bulletin by E. W. Sheets and R. H. Tuckwiller.....	1042	1-15
various rations, winter and summer.....	1042	7-11

	Bulletin No.	Page.
Calves—Continued.		
production on ranges, effect of drought.....	1031	2
rations, daily in winter.....	1042	7
winter rations, effect on pasture gains, etc., bulletin by E. W. Sheets and R. H. Tuckwiller.....	1042	1-15
wintering, cost of feed, etc.....	1042	12-14
Camphor tree, injury by red spider.....	1035	2, 3
Canada, sunflower silage experiments.....	1045	3-4, 8, 26, 27
Canal systems, Colorado, Cache la Poudre Valley, description, etc.	1026	26-51
Canals, irrigation, Colorado, water rights, comparison.....	1026	13-19
<i>Canarium commune</i> . See Almonds, Java.		
Canning, sweet potatoes—		
experimental tests of varieties.....	1041	6-13
heat penetration.....	1041	16
study of varieties, bulletin by C. A. Magoon and C. W. Culpepper.....	1041	1-34
<i>Carapa guianensis</i> , identification key.....	1050	2, 6-7
<i>Cariniana pyriformis</i> , identification key and description.....	1050	3, 12
Cars, loading with green lumber, directions.....	1037	23-24
Cattle—		
diseases, control on range.....	1031	74-75
feeding sunflower silage, experiments and results.....	1045	23-27
losses—		
from poisonous plants on ranges.....	1031	76
on ranges, decrease under management.....	1031	65-77
management, adjustments necessary in drought conditions....	1031	41-53
parasites control on ranges.....	1031	75
range, management during drought, and range management, bulletin by James T. Jardine and Clarence L. Forsling....	1031	1-84
See also Calves.		
Cedar—		
Mexican. See Cedrela.		
Spanish. See Cedrela.		
Cedrela, identification key and description.....	1050	3, 7-8
Celery, sprayed, poisonous residue at harvest time.....	1027	24, 48
<i>Ceratostoma piliferum</i> , cause of sap-stain in wood.....	1035	7-10
<i>Ceratostomella</i> , species, descriptions.....	1037	7-9
Cereals—		
experiments on dry land, Belle Fourche Experiment Farm, 1908-1919.....	1039	13-45
growing—		
experiments on Belle Fourche Experiment Farm, bulletin by John H. Martin.....	1039	1-72
experiments on dry land, South Dakota.....	1039	13-45
under irrigation, experiments in South Dakota.....	1039	45-70
CHAFFEE, F. E., and McFALL KERBEY, bulletin on "Self-service in retailing food products".....	1044	1-52
Cherries, sprayed, poisonous residue at picking time, investigations.....	1027	22, 49
Children, feeding, use of oils.....	1033	3, 4, 5
Chlorid, mercuric—		
use against cabbage blackleg.....	1029	2, 10-12
use against sap-stain and mold in woods.....	1037	37
Chlorophyll, suppression in plants, causes.....	1038	2-36
Chloroses—		
causes and conditions, studies.....	1038	2-6
infectious, description and studies.....	1038	6-13
Chlorosis, plant, histology, cytology, and relation to pecan rosette, bulletin by Frederick V. Rand.....	1038	1-42
Chrysopa—		
<i>Californica</i> , enemy of citrophilus mealybug.....	1040	19
<i>lateralis</i> , enemy of avocado red spider.....	1035	9

	Bulletin No.	Page.
Citrus—		
industry, damage by citrophilus mealybug.....	1040	1-2
orchards—		
infestation with mealybug and Argentine ants.....	1040	1-3, 8-15
spraying for control of mealybugs.....	1040	{ 13-15, 16, 18
treatment for control of Argentine ant, cost, etc.....	1040	{ 8-11, 18, 20
Coal—		
composition and destructive distillation.....	1036	7-11
tar, composition and manufacture.....	1036	7-18
<i>See also Tar, coal.</i>		
Cod-liver oil, digestibility, experiments.....	1032	3-5
<i>Colibacillosis tetraonidarum</i> , quail disease, cause of range depletion.....	1049	35
Colorado—		
Cache la Poudre—		
River, water diversions, 1916, 1917.....	1026	19-23
Valley, description, meteorology, soils, etc.....	1026	2-12
Valley, irrigation development.....	1026	2-79
Valley, irrigation of various crops.....	1026	{ 51-68, 83-84
Valley, topography, climate, soil, etc.....	1026	2-12
Fort Collins, climate records, 1887-1917.....	1026	3-5
irrigation canals, water rights, comparisons.....	1026	13-19
northern, irrigation, bulletin by Robert G. Hemphill.....	1026	1-35
water resources, for irrigation in Cache la Poudre Valley.....	1026	6-10
Conifers, "bluing," cause, discussion.....	1037	7-12
Copper sprays, metal deposits on fruits and vegetables, investigations.....	1027	4-9
Corn—		
acreage under irrigation, Colorado, Cache la Poudre Valley, 1916, 1917.....	1026	43
crop area and uses in south Georgia.....	1034	12-13
fat, blended, digestibility experiments.....	1033	11, 13, 14
losses from specified causes in various localities, 1909-1918....	1043	6, 8, 10
silage yields, comparison with sunflowers.....	1045	18
Cotton—		
Egyptian, industry increase by Department work.....	1030	17
losses—		
causes in Sumter County, Ga.....	1034	20
from specified causes, in various localities, 1909-1918....	1043	7, 9, 11
Meade—		
characteristics, substitute for sea-island, etc.....	1030	2-6, 8-22
comparison with long-staple and short-staple varieties....	1030	4, 23
growing experiments.....	1030	4-17
growing methods.....	1030	15-20
seed supply.....	1030	6-9
spinning tests, comparison with sea-island.....	1030	20-22, 24
substitution for sea-island, bulletin by G. S. Meloy and C. B. Doyle.....	1030	1-24
yield and prices, comparison with sea-island.....	1030	2-3, 20-22
production—		
cost, relation to farm organization.....	1034	58-72
in southern Georgia, importance as farm crop.....	1034	9-13
sea-island—		
production decline.....	1030	1-2
spinning tests, comparison with Meade.....	1030	20-22, 24
substitute, need for.....	1030	1-2, 23
Cottons, spinning tests of sea-island and Meade.....	1030	20-22, 24
Cottonseed—		
cake, feeding to calves and poor cows on ranges.....	1031	{ 67, 68, 70, 79
fat, blended, digestibility experiments.....	1033	{ 11-12, 13, 14
meal, feed value for calves.....	1042	7-11
<i>Coturnix</i> spp. <i>See Quail.</i>		
Cowpeas, crop area and uses in south Georgia.....	1034	12, 14

	Bulletin No.	Page.
Cows, range, supplemental feeding.....	1031	45-46, 68-71
Crabwood, identification key and description.....	1050	2, 6-7
Cranberries, sprayed, poisonous residue at harvest time.....	1027	24-25, 48
Cranberry—		
blackhead fireworm on Pacific coast, bulletin by H. K. Plank and Carl Heinrich.....	1032	1-46
bog management on Pacific coast.....	1032	3
bogs, treatment for control of blackhead fireworm.....	1032	22-37
industry on the Pacific Coast.....	1032	2
Credit agencies, farm, benefits to farmers.....	1048	25
Creosote—		
application of term.....	1036	3, 5-6
production from tars, methods.....	1036	19-21
specimens, experimental comparisons.....	1036	23-46
testing—		
apparatus for distilling tars, and method used.....	1036	27-34
methods, and specifications.....	1036	87-105
tests and results.....	1036	38-43
Creosotes—		
coal-tar—		
and water-gas tar, properties and testing methods, bulletin by Ernest Bateman.....	1036	1-114
comparison with water-gas creosotes.....	1036	44-46, 77-78
distillation specific gravity, etc., tables.....	1036	106-109
properties, physical, chemical, and toxic.....	1036	23-72
superiority over other preservatives.....	1036	103-104
commercial and laboratory, comparison.....	1036	35-37
domestic and imported, amount used in wood-treating plants..	1036	22
official specifications and testing methods.....	1036	87-105
properties.....	1036	47-86
sources and nature.....	1036	1-2, 6
water-gas—		
composition, properties, with comparisons.....	1036	73-76
distillation, specific gravity, etc., tables.....	1036	110-111
properties.....	1036	73-76
Crops—		
insurance—		
principles.....	1043	18-26
risks, losses, and principles of protection, bulletin by V. N. Valgren.....	1043	1-27
intertilled, farm practices in South Georgia.....	1034	16-17
loss or damage during growth, discussion.....	1043	2-4
losses annually from specified causes in various localities, 1909-1918.....	1043	5-12
protection by self-insurance and by contract insurance.....	1043	13-18
CROSSMAN, S. S., bulletin on " <i>Apanteles melanoscelus</i> , an im- ported parasite of the gipsy moth".....	1028	1-25
<i>Cryptolaemus montrouzieri</i> , enemy of citrophilus mealybug, distri- bution.....	1040	19-20
CULPEPPER, C. W., and C. A. MAGOON, bulletin on "A study of sweet-potato varieties with special reference to their canning quality".....	1041	1-34
Curing, sweet potatoes, changes.....	1041	5-6
Dairy cattle, feeding sunflower silage, experiments and results..	1045	23-36
Deer—		
conservation in Pennsylvania.....	1049	30, 34, 39
fat, digestibility experiments.....	1033	8-9
hunting—		
limitations and conditions in different States.....	1049	15-16
States permitting.....	1049	3-4, 15
number killed, records in various States and provinces.....	1049	3, 19, 23, 37, 38
number, reduction, means of increase, etc.....	1049	2-4
ranges, restocking depleted areas.....	1049	36-39
value for meat, estimates of resources.....	1049	12-15

	Bulletin No.	Page.
<i>Dendroctonus ponderosae</i> , dissemination of blue-stair fungus in woods.....	1037	40
Desiccation, treatment of cabbage seed for blackleg control.....	1029	5-7
DEUEL, HARRY J., jr., and ARTHUR D. HOLMES, bulletin on "Digestibility of cod-liver, Java-almond, tea-seed and watermelon seed oils, deer fat, and some blended hydrogenated fats".....	1033	1-15
Digestibility, oils, cod-liver, Java-almond, tea-seed, watermelon-seed, deer fat and hydrogenated fats, bulletin by Harry J. Deuel, jr., and Arthur D. Holmes.....	1033	1-15
Digestion, experiments with oils and fats.....	1033	3-15
Dip, fungi control in woods, experiments and studies.....	1037	32-48, 51
Diseases—		
chlorotic list and notes.....	1038	13
plant, losses caused by, 1909-1918.....	1043	6, 7, 8, 9, 10, 11
DIXON, H. M., H. W. HAWTHORNE, and FRANK MONTGOMERY, bulletin on "Farm management and farm organization in Sumter County, Ga.".....	1034	1-97
Dooley sweet potato, canning value, and description.....	1041	8, 11, 17, 23, 30
DOYLE, C. B., and G. S. MELOY, bulletin on "Meade cotton: An upland long-staple variety replacing sea-island".....	1030	1-24
Drainage, conditions in Colorado, Cache la Poudre Valley.....	1026	12
Drought—		
losses caused by, 1909-1918.....	1043	6, 7, 8, 9, 10, 11
problems, management of ranges and range cattle, bulletin by James T. Jardina and Clarence L. Forsling.....	1031	1-84
recurrence in—		
New Mexico and effects on ranges.....	1031	11-18, 19-25
Southwest.....	1031	11-13
Dry land—		
sunflower growing, experiments.....	1045	5-7
farming—		
South Dakota, experiments with cereals.....	1039	13-45
sunflower culture, directions.....	1045	6-7
Early Red Carolina, sweet potato, canning value and description..	1041	8, 11, 14, 17, 25, 30
Egyptian cotton, industry in Southwest, establishment and spacing methods.....	1030	17
Elk—		
enumeration and value.....	1049	24, 25
occurrence, distribution, hunting restrictions, and need of refuges.....	1049	4-5
Refuge, Jackson Hole, Wyo., purchase and cost.....	1049	45, 46
restocking, and transfers, 1905-1920.....	1049	39-41
Elm, injury by avocado red spider in South.....	1035	4
Emmer, growing—		
on dry land, experiments in South Dakota.....	1039	36
under irrigation, experiments in South Dakota.....	1039	59-60
ENGELBERT, ELMER, and V. N. VALGREN, bulletin on—		
"Bank loans to farmers on personal and collateral security".....	1048	1-26
"Farm mortgage loans by banks, insurance companies, and other agencies".....	1047	1-23
<i>Entandrophragma candollei</i> , identification key and description...	1050	3, 8-9
Experiment station, Kansas, studies of wheat-rust resistance.....	1046	4-32
Farm—		
expenses, distribution in Georgia, Sumter County, 1913, 1918.	1034	25-28
loans, security, personal and collateral, nature.....	1048	20-22
products—		
perishable handling by self-service plan.....	1044	35-39
price variations in Georgia, 1911-1920.....	1034	45
Sumter County, Ga., sales and prices, 1913, 1918.....	1034	43-46

Farmers—	Bulletin No.	Page.
colored, owners and tenants, operations in Sumter County, Ga.	1037	3-8
		10-22
		28-40
independence, meaning and limitations.....	1043	1-2
loans by banks on personal and collateral security, bulletin by V. N. Valgren and Elmer E. Engelbert.....	1048	1-26
mortgage loans by banks, insurance companies, and other agencies, bulletin by V. N. Valgren and Elmer E. Englebert.	1047	1-23
supplies from farm in south Georgia.....	1034	36-37
Farming, Sumter County, Ga., methods, crops, etc.....	1034	8-21
Farms—		
capital invested, distribution and relation to size of farm in south Georgia.....	1034	28-31
colored-tenant, Sumter County, Ga., business summary 1913, 1918.....	1034	88-97
earnings in Sumter County, Ga., 1913, 1918.....	1034	31-38
game, private breeders.....	1049	43-44
market value increase, ownership transfers, etc.....	1047	21
management and organization, Sumter County, Ga., bulletin by H. W. Hawthorne, H. M. Dixon, and Frank Montgomery	1034	1-97
mortgage—		
debt, 1919, comparison with 1910.....	1047	22
loans, by banks, insurance companies, and other agencies, bulletin by V. N. Valgren and Elmer Engelbert.....	1047	1-23
mortgages in Georgia, Sumter County, loans and interest rates.	1034	39-40
operation—		
cost, Georgia, Sumter County, white and colored.....	1034	41, 73-97
in Sumter County, Ga., factors in efficiency.....	1034	50-58
organization and improvement, factors causing.....	1034	55-58
receipts, distribution in south Georgia, 1913, 1918.....	1034	21-25
size, relation to cotton production and cost, southern Georgia.	1034	50-55, 63-68
tenures in Sumter County, Ga.....	1034	8-11
white owners, Sumter County, Ga., business summary, 1913, 1918.....	1034	73-87
Fat, deer, digestibility experiments.....	1033	8-9
Fats—		
blended hydrogenated, digestibility, experiments.....	1033	9-15
deer, hydrogenated, and some oils, digestibility, bulletin by Harry J. Deuel, jr., and Arthur D. Holmes.....	1033	1-15
hydrogenated, and deer, and other oils, digestibility, bulletin by Harry J. Deuel, jr., and Arthur D. Holmes.....	1033	1-15
value as food, discussion.....	1033	1-2
vegetable, blended, digestibility experiments.....	1033	9-15
Feed—		
dairy and beef cattle, value of sunflower silage.....	1045	23-27
hogs, sunflower-silage experiments.....	1045	29
reserve, on ranges for emergency.....	1031	69-71
sheep, value of sunflower silage.....	1045	27-29
Feeding, calves—		
in winter, gains from various rations, and cost.....	1042	3-15
on ranges.....	1031	67-68, 79
Feeds, calf wintering, costs and gains.....	1042	7-11
Fees, hunting license, receipts from.....	1049	11-12
Fireworm, blackhead—		
control by disease and insect enemies.....	1032	20-22
introduction to cranberry bogs of Northwest.....	1032	4
occurrences, life history, and habits.....	1032	4-20
of cranberry on Pacific coast, bulletin by H. K. Plank and Carl Heinrich.....	1032	1-46
of cranberry, technical description, by Carl Heinrich.....	1032	42-46
FISKE, W. F., work on gipsy-moth parasites.....	1028	14-16, 17
Flax—		
growing on dry land, experiments in South Dakota.....	1039	42-45
seeding rates and dates, dry-land and irrigation farming, South Dakota.....	1039	12, 67-68

	Bulletin No.	Page.
Flaxseed, losses from specific causes, 1909-1918.....	1043	6, 8, 10
Flooding, cranberry bogs, for insect control.....	1032	22, 34, 40
Floods, losses caused by, 1909-1918.....	1043	{ 6, 7, 8, 9, 10, 11
Florida, avocado growing, red spider injury, investigations.....	1035	2-14
Flour, sweet-potato, manufacture.....	1041	6, 33
Fluorids, use against wood fungi.....	1037	36-37
Fly, lacewing, enemy of avocado red spider.....	1035	9
Food—		
products—		
distribution, relation of cost to price to producer.....	1044	1-2
perishable, handling in self-service stores.....	1044	39
retailing, distribution cost, studies.....	1044	1-2
retailing, self-service plan, bulletin by F. E. Chaffee and McFall Kerbey.....	1044	1-52
shrinkage, considerations in retail business.....	1044	43-49
sweet potato, value.....	1041	1-3
Forage, production on New Mexico range, relation to protection..	1031	25-41
Formaldehyde, treatment of cabbage seed for blackleg control....	1029	2, 7-9
FORSLING, CLARENCE L., and JAMES L. JARDINE, bulletin on "Range and cattle management during drought".....	1031	1-84
Frost, losses caused by, 1909-1918.....	1043	{ 6, 7, 8, 9, 10, 11
Frosts, killing, at Belle Fourche Experiment Farm, dates, 1908- 1914.....	1039	10-11
Fruits—		
handling in self-service stores.....	1044	35-39
sprayed, and vegetables, poisonous metals on, bulletin by W. D. Lynch, C. C. McDonnell, J. K. Haywood, A. L. Quaintance, and M. B. Waite.....	1027	1-66
Fungi, factors favoring growth.....	1037	14-17
Fungicides, use on cabbage seed, results, laboratory work.....	1029	3-13
Fungus disease of blackhead fireworm of cranberry.....	1032	20-21
Game—		
big—		
in United States, value.....	1049	25
protection of females by hunting laws.....	1049	28-29
breeding, to increase supply.....	1049	42-44
enumeration, and value.....	1049	23-25
killing, records.....	1049	18-23
kinds in the United States, description and location.....	1049	2-9
maintenance cost.....	1049	44-47
protection—		
by hunting laws, various sections.....	1049	26-29
cost of refuges, National and State.....	1049	45-47
refuges—		
establishment.....	1049	29-33
in States, object and development.....	1049	31-33
resources—		
increase methods.....	1049	25-44
survey suggestions.....	1049	47-48
restocking depleted areas.....	1049	34-41
value—		
as National resource, bulletin by T. S. Palmer.....	1049	1-48
as source of recreation.....	1049	10-11
estimates by State officials.....	1049	12-15
to the farmer, means of increasing income.....	1049	9-10
wardens, cost, and organization of service.....	1049	44-45
Georgia—		
crops, yields, 1911-1920.....	1034	20
southern—		
changes in land utilization, 1913-1918.....	1034	3-4
crop yields.....	1034	17-21

Georgia—Continued.

	Bulletin No.	Page.
Sumter County—		
area, colored and white population, land utilization, etc.	1034	5-8
farm management and organization, bulletin by H. W. Hawthorne, H. M. Dixon, and Frank Montgomery.	1034	1-97
soils, topography, climate, etc.	1034	5-6
Ginning, Meade cotton, difficulties.	1030	7-8
Gipsy moth—		
parasite, <i>Apanteles melanoscelus</i> , bulletin by S. S. Crossman.	1028	1-25
parasitizing by <i>Apanteles melanoscelus</i> , details.	1028	6-10, 20-21
Goats, mountain, enumeration and value.	1049	24, 25
Golden skin, sweet potato, canning value and description.	1041	8, 11, 13, 14, 17, 26, 30
Grain—		
acreage under irrigation, Colorado, Cache la Poudre Valley, 1916-1917.	1026	43
mixtures, feed value for calves.	1042	7-11
Grains—		
crop area in south Georgia.	1034	12-14
growing on irrigated land, Belle Fourche Farm, yield comparison.	1039	64-65, 72
mixture, experiments on irrigated land, Belle Fourche Farm.	1039	62-63, 72
wheat and flax mixtures, experiments on irrigated land, Belle Fourche Farm.	1039	63-64, 72
yield, relation of precipitation.	1039	6-8
yields on dry land, comparison.	1039	41-42
Grama grass—		
occurrence and importance in South Dakota.	1039	4
value on ranges.	1031	8-9, 20-22, 26-31, 33
Grapes, sprayed, poisonous residue at harvest time, investigations.	1027	27-30, 48
Grass—		
buffalo, native vegetation of Belle Fourche region.	1039	4
grama, native vegetation of Belle Fourche region.	1039	4
western wheat, occurrence in South Dakota.	1039	4
Grasses, wild, occurrence and importance in South Dakota.	1039	4
Grazing—		
capacity of Southwest ranges.	1031	34-41
effects on ranges, value of protection.	1031	25-34
Greeley, Canal No. 2, Colorado, description and capacity.	1026	37-39
Grevillia robusta, injury by red spider.	1035	3
Groceries—		
distribution, self-service method.	1044	2-52
loss from spoilage in self-service stores.	1044	38-39
selling by self-service plan, bulletin by F. E. Chaffee and McFall Kerbey.	1044	1-52
Gum, red, use as substitute mahogany, identification key and description.	1050	1, 4, 15
Gun, spray, comparison with spray rod.	1035	13
Hail—		
insurance, risks and premiums, several States.	1043	16
losses caused by, 1909-1918.	1043	6, 7, 8, 9, 10, 11
Harvesting, sunflowers, methods.	1045	12-13
HAWTHORNE, H. W., H. M. DIXON, and FRANK MONTGOMERY, bulletin on "Farm management and farm organization in Sumter County, Ga."	1034	1-97
Hay—		
acreage under irrigation, Colorado, Cache la Poudre Valley, 1916, 1917.	1026	43
crop area in south Georgia.	1034	12, 15
losses from specified causes, in various localities, 1909-1918.	1043	6-7, 9, 11
Hays, feed value for calves.	1042	7-11

	Bulletin No.	Page.
HAYWOOD, J. K., W. D. LYNCH, C. C. McDONNELL, A. L. QUAIN- TANCE, and M. B. WAITE, bulletin on "Poisonous metals on sprayed fruits and vegetables".....	1027	1-66
HEINRICH, CARL— and H. K. PLANK, bulletin on "The blackhead fireworm of cranberry on the Pacific coast".....	1032	1-46
description of cranberry blackhead fireworm.....	1032	42-46
<i>Helianthus annuus</i> . See Sunflower.		
HEMPHILL, ROBERT G., bulletin on "Irrigation in northern Colorado".....	1026	1-35
Herds, range, improvement by selection and breeding.....	1031	55-58
Hog millet. See Proso.		
Hogs, feeding sunflower silage, experiments and results.....	1045	29
HOLMES, ARTHUR D., and HARRY J. DEUEL, jr., bulletin on "Di- gestibility of cod-liver, tea-seed, and watermelon-seed oils, deer fat, and some blended hydrogenated fats".....	1033	1-15
Honeydew, secretion by mealybugs, and deposit of smut.....	1040	3
HOWARD, NATHANIEL O., bulletin on "Control of sap-stain, mold, and incipient decay in green wood with special reference to vehicle stock".....	1037	1-55
Hunting— bag limits, in various States.....	1049	16, 18
excessive, limitations in different States.....	1049	15-18
grounds, public, notable examples.....	1049	29-31
laws for game protection in various sections.....	1049	26-29
license fees, receipts from.....	1049	11-12
Idaho— Experiment Station, work on sunflower silage.....	1045	6, 12, 22, 23
game value, estimate by game warden.....	1049	12, 13
quail-protection laws.....	1049	17
Illinois, game farm, maintenance and work, 1912.....	1049	47
Indiana, game refuges, 1899-1915, conditions and results.....	1049	32-33
Inoculation, wheat, with <i>Puccinia graminis tritici</i> , experiments, results.....	1046	4-24
Insecticides— poisonous, metal deposits on fruits and vegetables, investiga- tions, bulletin by W. D. Lynch, C. C. McDonnell, J. K. Haywood, A. L. Quaintance, and M. B. Waite.....	1027	1-66
use against red spider.....	1035	11-15
Insects— enemies of avocado red spider.....	1035	9-11
hosts of <i>Apanteles melanoscelus</i>	1028	13
losses caused by, 1909-1918.....	1043	6, 7, 8, 9, 10, 11
Insurance, crop— principles.....	1043	18-26
risks, losses, and principles of protection, bulletin by V. N. Valgren.....	1043	1-27
Interest— collection on farm loans.....	1048	19-20, 25
rates— by banks on farm loans.....	1048	7-14, 16-17
on farm loans, reported by banks, March, 1921, by States.	1048	10-20
Iowa, quail-protection laws.....	1049	17
<i>Ipomoea batatas</i> . See Sweet potato.		
Irrigation— cereals, experiments in South Dakota.....	1039	45-70
Colorado, northern, bulletin by Robert G. Hemphill.....	1026	1-85
farm, Cache la Poudre Valley, Colo.....	1026	79, 83-84
<i>Ivar axillaris</i> , occurrence and economic importance in South Da- kota.....	1039	4-5

	Bulletin No.	Page.
JARDINE, JAMES T., and CLARENCE L. FORSLING, bulletin on "Range and cattle management during drought".....	1031	1-83
Jornada Range Reserve, description, range types, etc.....	1031	4-41, 43-53
Kanred wheat, agronomic value.....	1046	26-27
Kansas—		
experiment station, studies of wheat-rust resistance.....	1046	4-32
quail-protection laws.....	1049	17
KERFEY, McFALL, and F. E. CHAFFEE, bulletin on "Self-service in retailing food products".....	1044	1-52
Khaya spp, identification key, and description.....	1050	3, 10-12
KOEHLER, ARTHUR, bulletin on "The identification of true mahogany, certain so-called mahoganies and some common substitutes.....	1050	1-18
Ladybirds, value as enemies of avocado red spider.....	1035	10
Ladybugs, value in control of cranberry fireworm.....	1032	21
Landlords, southern Georgia, white and colored, numbers, efficiency, etc.....	1034	8-97
Larimer—		
and Weld canal, Colorado, description, capacity, etc.....	1026	30-34
County canal, Colorado, description and capacity.....	1026	34-37
Latex, presence in sweet potatoes, note.....	1041	6
Lauaan, red, identification key, and description.....	1050	3, 10-12
Laws, hunting, for game protection in various sections.....	1049	26-29
Lead arsenate, use in sprays, metal deposits on fruits and vegetables.....	1027	9-16
Leaf rust, resistance of wheat varieties.....	1046	26
Lemon, treatment for control of Argentine ant and mealybug.....	1040	8-19
Leptothrips mali, enemy of avocado red spider.....	1035	10
Leucopis bella, enemy of citrophilus mealybug.....	1040	19
License fees, hunting, receipts from.....	1049	11-12
Life insurance companies, farm-mortgage loans.....	1047	4
Lime, use and value on soils.....	1031	16-39
Liming, soil, practices in Southeast.....	1031	16-39
Lime-sulphur spray, avocado red spider, formula.....	1035	12, 15
Liquidambar styraciflua, identification key and description.....	1050	2, 6-7
Live stock—		
distribution on ranges, and salting.....	1031	52-53
Georgia, number on farms, 1911-1920.....	1034	49
industry in Southwest, effect of droughts.....	1031	1-4
young, increasing growth on ranges, supplemental feeding, etc.....	1031	77-79
Loading, cars with vehicle stock, requirements.....	1037	23-32
Loans—		
bank—		
to farmers, fluctuations, by months, etc.....	1048	4-6
to farmers, on personal and collateral security, bulletin by V. N. Valgren and Elmer E. Engelbert.....	1043	1-26
farm—		
maximum term of personal and collateral loans.....	1048	22-23
mortgage, amount and sources, estimates, 1920, by divisions and States.....	1047	1-3, 22
mortgage, by banks, insurance companies, and other agencies, bulletin by V. N. Valgren and Elmer E. Engelbert.....	1047	1-23
mortgage, data, nature and comparability.....	1047	2
mortgage, held by banks, December 31, 1920, by divisions and States.....	1047	8-10
mortgage, total of banks, 1920.....	1048	4
number, amount, etc., by States.....	1047	2-3
term and repayment methods.....	1047	21
short—		
interest to farmers, March, 1921.....	1048	6-17, 25-26
to farmers, interest rates by banks.....	1048	7-14
London purple, spray deposits on fruits and vegetables, investigations.....	1027	2-3, 7, 8
"Long short cotton," name for Meade cotton.....	1030	4

	Bulletin No.	Page-
Louisiana—		
game—		
estimate by Conservation Commission.....	1049	12, 13
refuges.....	1049	46-47
Pass a Loutre, public hunting grounds.....	1049	30
Lumber—		
green—		
handling and storage for fungi control.....	1037	24-32, 51
packing in cars for prevention of mold.....	1037	{ 23-24, 50-51
treatment for control of sap-stain and mold.....	1037	32-41
seasoning and kiln drying, for fungi control.....	1037	25-27, 51
steaming for fungi control, experiments.....	1037	28-32
LYNCH, W. D., C. C. McDONNELL, J. K. HAYWOOD, A. L. QUAIN- TANCE, and M. B. WAITE, bulletin on "Poisonous metals on sprayed fruits and vegetables".....	1027	1-66
MAGOON, C. A., and C. W. CULPEPPER, bulletin on "A study of sweet-potato varieties with special reference to canning quality".....	1041	1-34
Mahoganies, identification keys, and description of species, bulle- tin by Arthur Koehler.....	1050	1-16
Mahogany—		
African, identification key and description.....	1050	3, 9-10
Columbian, identification key and description.....	1050	3, 12
identification key and description.....	1050	2-18
identifications of true and substitutes, bulletin by Arthur Koehler.....	1050	1-18
Liberville, identification key and description.....	1050	4, 13
Philippine—		
identification key and description.....	1050	3, 10-12
species, occurrence, etc.....	1050	11-12
white, identification key and description.....	1050	4, 16
Maine, game records 1894-1913.....	1049	19
Manufacturers, vehicle, loss from sap-stain, mold, and decay of green stock.....	1037	1-3, 18-21
Marketing, food products, self-service plan, bulletin by F. E. Chaffee and McFall Kerbey.....	1044	1-52
MARTIN, JOHN H., bulletin on "Experiment with cereals on the Belle Fourche Experiment Farm, Newell, S. Dak.".....	1039	1-72
Massachusetts—		
deer and pheasants, killing records, 1910-1920.....	1049	19
gipsy-moth parasite work, introduction and dispersion.....	1028	{ 1, 16-18, 21-25
MCDONNELL, C. C., W. D. LYNCH, J. K. HAYWOOD, A. L. QUAIN- TANCE, and M. B. WAITE, bulletin on "Poisonous metals on sprayed fruits and vegetables".....	1027	1-66
Meade cotton, substitution for sea-island cotton, bulletin by G. S. Meloy and C. B. Doyle.....	1030	1-24
<i>See also</i> Cotton, Meade.		
Mealybug, citrophilus—		
control, bulletin by R. S. Woglum and A. D. Borden.....	1040	1-20
description and life history.....	1040	4-7
distribution and economic importance.....	1040	2-4, 9
injury to citrus industry, nature and extent.....	1040	3
MELCHERS, LEO E., and JOHN H. PARKER, bulletin on "Rust resistance in winter-wheat varieties".....	1046	1-32
MELOY, G. S., and C. B. DOYLE, bulletin on "Meade cotton: An upland long-staple variety replacing sea-island".....	1030	1-24
Mercuric chlorid, treatment of cabbage seed for blackleg control. Metals, poisonous, on sprayed fruits and vegetables, bulletin by W. D. Lynch, C. C. McDonnell, J. K. Haywood, A. L. Quain- tance, and M. B. Waite.....	1027	2, 10-12 1-66
Michigan—		
Experiment Station, work on sunflower silage.....	1045	9, 22, 23
game value, estimate by State warden.....	1049	13
Miles sweet potato, canning value and description.....	1041	8, 26, 30
Millet, hog. <i>See</i> Proso.		

	Bulletin No.	Page.
Minnesota—		
game killing in 1919 and 1920.....	1049	20-21
Superior State Game refuge.....	1049	31
Moisture, excess, crop losses caused by, 1909-1918.....	1043{	6, 7, 8, 9, 10, 11
Molds—		
control in—		
green vehicle stock, and sap-stain and decay, bulletin by Nathaniel O. Howard.....	1037	1-55
vehicle woods.....	1037	21-50
occurrence in woods, species, description, and determination.	1037	12-14
Montana—		
Experiment Station, work on sunflower silage.....	1045{	4, 6, 10- 14, 19-23
hail insurance on crops.....	1043	16
Montana, Bison Range purchase and cost.....	1049	45
MONTGOMERY, FRANK, H. W. HAWTHORNE, and H. M. DIXON, bulletin on "Farm management and farm organization in Sumter County, Ga.".....	1034	1-97
Moose—		
distribution and hunting conditions.....	1049	5
enumeration and value.....	1049	24, 25
killing records for Nova Scotia and Alberta, 1907-1920.....	1049	22-23
Mortgages, farm loan—		
and interest in Sumter County, Ga.....	1034	39-40
by banks, insurance companies, and other agencies, bulletin by V. N. Valgren and Elmer Engelbert.....	1047	1-23
Mosaic disease, infectious, description, occurrence, etc., studies...	1038	8-13
Moth—		
blackhead fireworm of cranberry, description and habits.....	1032	17-19
gipsy. <i>See</i> Gipsy moth.		
satin, host of gipsy-moth parasite.....	1028	12-13
tussock, host of <i>Apanteles melanoscelus</i>	1028	13
MOZNETTE, G. F., bulletin on "The red spider on the avocado"...	1035	1-15
Mullihan sweet potatoes, canning value and description.....	1041{	8, 11, 27, 30
Nancy Hall sweet potato, description, canning quality, etc.....	1041{	8, 9-13, 17-19, 22- 24, 27, 30
Nebraska—		
Experiment Farms, work on sunflower silage.....	1045{	10, 21- 22, 25
hail insurance on crops.....	1043	16
Needle grass, occurrence in South Dakota.....	1039	4
Negroes—		
farm management in southern Georgia.....	1034	10-97
farming in southern Georgia, comparison with operations by white farmers.....	1034	12-97
New—		
England, gipsy-moth control by parasite, <i>Apanteles melanos-</i> <i>celus</i>	1028{	16-18, 21-25
Mexico—		
Jornada Range Reserve, description and range conditions	1031{	4-41, 43-53
range problems during drought.....	1031	84
Southern cattle-breeding section, management of herds..	1031	42-53
York—		
Adirondack Preserve, public hunting grounds.....	1049	30
game farms, breeding for distribution, cost, etc.....	1049	42, 47
game protection service, organization and cost.....	1049	44-45
game records, 1918.....	1049	19, 22
game value, estimate by State official.....	1049	13-14

	Bulletin No.	Page.
Nicotine—		
oleate, formulas for cranberry spray.....	1032	24-25
sulphate—		
formulas and results for cranberry spray.....	1032	{ 24, 33, 34- 35, 39, 40
spray for avocado red spider, formula, etc.....	1035	12, 15
North Dakota, hail insurance on crops.....	1043	16
Nova Scotia, big game killing, 1908-1920.....	1049	22
Nursery, grain rust, Manhattan, Kans., experiments with wheat varieties.....	1046	4-14
Oak—		
Australian silk, injury by red spider.....	1035	3
white, injury by red spider.....	1035	4
Oats—		
growing—		
on dry land, experiments in South Dakota.....	1039	27-32
under irrigation, experiments in South Dakota.....	1039	52-56
irrigation in Colorado, 1916, 1917.....	1026	64, 84
losses from specified causes in various localities, 1909-1918...}	1043	6, 8, 10
seeding rates and dates, dry-land and irrigation farming, } South Dakota.....	1039	{ 12, 31- 32, 56
Ohio, quail-protection laws.....	1049	17
Oil—		
creosote. <i>See</i> Creosote.		
cod-liver, digestibility experiments.....	1033	3-5
Java almond, digestibility experiments.....	1033	5-6
sunflower seed, production and uses.....	1045	1-2
tea-seed, digestibility experiments.....	1033	6-7
watermelon-seed, digestibility experiments.....	1033	7-8
Oils—		
cod-liver, and other oils and fats, digestibility, bulletin by Harry J. Deuel and Arthur D. Holmes.....	1033	1-15
wood preservatives—		
sources and nature.....	1036	6
specifications by various associations.....	1036	103-106
Orange, treatment for control of Argentine ant and mealybug....	1040	8-19
Orchards, citrus—		
infestation with citrophilus mealybug.....	1040	1-3, 8-15
treatment for control of Argentine ant, cost, etc.....	1040	{ 8-11, 18, 20
Oregon—		
cranberry industry, and occurrence of blackhead fireworm...}	1032	2-6
game—		
farm, cost and work.....	1049	47
value, estimate by W. L. Finley.....	1049	14
Pacific coast, blackhead fireworm of cranberry, bulletin by H. K. Plank and Carl Heinrich.....	1032	1-46
PALMER, T. S., bulletin on "Game as a National resource".....	1049	1-48
Parasite, gipsy-moth, description, life history, introduction and dispersion, bulletin by S. S. Crossman.....	1028	1-25
Parasites, cattle, control on ranges.....	1031	75
Paris green, spray deposits on fruits and vegetables, investigations.	1027	1-3, 8, 12
PARKER, JOHN H., and LEO E. MELCHERS, bulletin on "Rust resistance in winter-wheat varieties".....	1046	1-32
Parsley, wild, occurrence in western South Dakota.....	1039	4
Partridges, Hungarian, restocking depleted area, results.....	1049	35-36
Pastures, New Mexico, Jornada Range Reserve, capacity, etc....	1031	4-41
Peaches, sprayed, poisonous residue on fruit at picking time, } investigations.....	1027	{ 18-22, 48-49
Peanut fat, blended, digestibility experiments.....	1033	12-13, 14
Peanuts, crop area and uses in south Georgia.....	1034	12, 15
Pears, sprayed, poisonous residue at picking time, investigations..}	1027	{ 31-32, 48-49
Peas, acreage under irrigation, Colorado, Cache la Poudre Valley, 1916, 1917.....	1026	43

Pecan—		
rosette, histology, cytology, and relation to other chlorotic diseases, bulletin by Frederick N. Rand.....	Bulletin No. 1038	Page. 1-42
tree, injury by avocado red spider.....	1035	4
trees, transplanting and fertilizing, experiments.....	1038	30-31
Pennsylvania—		
Experiment Station, work on sunflower silage feeding.....	1045	24-25
game—		
killing in 1920.....	1049	20
preserves, refuges for hunted animals.....	1049	30, 31
Peruvian sunflower. <i>See</i> Sunflower.		
<i>Peucedanum foeniculeaceum</i> , occurrence in western South Dakota..	1039	4
Pheasant, breeding to increase supply.....	1049	42, 44
Pheasants—		
importation, 1906-1915, results.....	1049	36
killing records in various States.....	1049	19-22
Phenol, Compound No. 1, spraying experiments.....	1032	26
<i>Phoma Vignum</i> . <i>See</i> Blackleg, cabbage.		
PLANK, H. K., and CARL HEINRICH, bulletin on "The blackhead fireworm of cranberry on the Pacific coast".....	1032	1-46
Plants, absorption studies.....	1038	5
Plums, sprayed, poisonous residue on fruit at picking time.....	1027	23, 49
Poison—		
baits for Argentine ants.....	1040	9, 18
plants, avoidance on ranges.....	1031	76
Poisons—		
metal on sprayed fruits and vegetables, bulletin by W. D. Lynch, C. C. McDonnell, J. K. Haywood, A. L. Quaintance, and M. B. Waite.....	1027	1-66
residues from sprays, determination methods.....	1027	16-18
<i>Porthetria dispar</i> . <i>See</i> Gipsy moth.		
Porto Rico sweet potato, description, canning quality, etc.....	1041	8, 10-12, 13, 17-19, 21-23, 27, 30
Potatoes—		
acreage under irrigation, Colorado, Cache la Poudre Valley, 1916, 1917.....	1026	43
irrigation in Colorado, 1916, 1917.....	1026	67-68, 84
losses from specified causes, in various localities, 1909-1918..	1043	6, 8, 11
Poudre Canal, Colo., description and capacity.....	1026	39-42
Poverty weed, occurrence and economic importance in South Dakota.....	1039	4-5
Precipitation—		
arid Southwest, tables.....	1031	11-18
data for fruit-growing sections.....	1027	49-57
relation to yield of grains, South Dakota.....	1039	6-8
Preservatives, wood—		
tar-cresote solutions.....	1036	79-83
coal-tar, and water-gas tar creosotes, properties and testing methods, bulletin by Ernest Bateman.....	1036	1-114
use for control of sap-stain and mold.....	1037	47-48
Proso—		
growing—		
on dry land, experiment in South Dakota.....	1039	37-40
under irrigation, experiments in South Dakota.....	1039	61-62
seeding rates and dates, dry-land and irrigation farming, South Dakota.....	1039	12
yields on dry land.....	1039	38, 39, 40
<i>Pseudococcus</i> —		
<i>citrophilus</i> . <i>See</i> Mealybug, citrophilus.		
<i>gahani</i> —		
description.....	1040	5
<i>See also</i> Mealybug, citrophilus.		
<i>Puccinia</i> —		
<i>graminis tritici</i> , inoculation of wheat, experiments.....	1046	4-24
<i>triticea</i> , leaf rust of wheat, epidemics, etc.....	1046	26

Quail—	Bulletin No.	Page.
disease—		
cause of depletion of birds.....	1049	35
presence in Mexican stock.....	1049	35
distribution, hunting restrictions, and sale prohibitions.....	1049	7
hunting limitations and conditions in different States.....	1049	16-18
restocking depleted areas, efforts and results.....	1049	34-35, 36
QUAINTANCE, A. L. W. D. LYNCH, C. C. McDONNELL, J. K. HAYWOOD, and M. B. WAITE, bulletin on "Poisonous metals, on sprayed fruits and vegetables".....	1027	1-66
Rabbit, hunting conditions, 1920.....	1049	17
Rabbits, distribution, numbers killed, and value as meat supply..	1049	6
Rainfall, relation to development of cabbage blackleg.....	1029	14-17
RAND, FREDERICK V., bulletin on "Pecan rosette: Its histology, cytology, and relation to other chlorotic diseases".....	1038	1-42
Range management, publications of Department.....	1031	82-83
Ranges—		
drought conditions, management, and management of cattle, bulletin by James T. Jardine and Clarence L. Forsling.....	1031	1-84
New Mexico, vegetation types, and capacity.....	1031	4-41
seasonal use, Joinada Range Reserve.....	1031	50-52
stocking to provide for drought.....	1031	38-41
Rations, winter, for calves—		
cost per pound gain, etc.....	1043	11-14
effect on pasture gains, bulletin by E. W. Sheets and R. H. Tuckwiller.....	1042	1-15
Red spider on avocado, bulletin by G. F. Moznette.....	1035	1-15
<i>See also</i> Spider, red.		
Reservoirs, Cache la Poudre Valley, location, types, etc.....	1026	69-79
<i>Rhopobota naevana</i> systemic description.....	1032	42-46
<i>See also</i> Fireworm, blackhead.		
Rice, losses from specified causes, in various localities, 1909-1918..	1043	6, 8, 10
ROBERTSON, JAMES W., work on sunflower silage mixture.....	1045	3-4
Rod, spray, comparison with spray gun.....	1035	13
Rosette—		
detection methods and control studies.....	1038	17-19
histological and cytological studies.....	1038	19-30
peach—		
notes.....	1038	7
similarity to peach yellows.....	1038	7
pecan—		
distribution, description, control studies.....	1038	13-31
experiments and studies.....	1038	31-36
histology, cytology, and relation to other chlorotic diseases, bulletin by Frederick V. Rand.....	1038	1-42
literature cited.....	1038	37-42
Rubber, compound, preparation from sweet potatoes.....	1041	6
Rural credit, personal and collateral, December 31, 1920.....	1048	2-4, 25
Russia, sunflower growing, varieties and uses.....	1045	8
Rust—		
grain, experiments with wheat at Manhattan, Kans.....	1046	4-14
sunflower, prevention by rust-proof varieties.....	1045	9, 30
Rye—		
growing—		
on dry land, experiments in South Dakota.....	1039	37
under irrigation, experiments in South Dakota.....	1039	60-61
seeding, rates and dates, dry-land and irrigation farming, South Dakota.....	1039	12
Salting, stock, importance on ranges.....	1031	53
Sapeli, identification key, and description.....	1050	3, 8-9
Sap-stain—		
control—		
in green vehicle stock, and control of mold and decay, bulletin by Nathaniel O. Howard.....	1037	1-55
measures.....	1037	21-50
description, kinds, causes, etc.....	1037	1-12
vehicle woods, loss from and economic importance.....	1037	18-21

	Bulletin No.	Page.
<i>Scilothrips sexmaculatus</i> , enemy of avocado red spider.....	1035	9
<i>Scymnus</i> —		
<i>sordidus</i> , enemy of citrophilus mealybug.....	1040	19
spp., black ladybirds, enemies of the avocado red spider....	1035	10
Sea-island cotton, replacement with Meade cotton, bulletin by G. S. Meloy and C. B. Doyle.....	1030	1-24
<i>See also</i> Cotton, sea-island.		
Seasoning, lumber, methods.....	1037	25-27
Seed—		
cabbage—		
blackleg control in, relation of treatment and rainfall, bulletin by J. C. Walker.....	1029	1-27
sources and importance of freedom from disease.....	1029	23-25
treatment for control of blackleg.....	1029	3-23
Meade cotton—		
Department supply to cotton growers, conditions.....	1030	6-9
selection, distribution, etc.....	1030	7, 11-14, 23
sunflower—		
areas in United States, location, and crop.....	1045	3
production, yield, and uses.....	1045	1-3
tea, oil from, digestibility.....	1033	6-7
watermelon, oil from, digestibility.....	1033	7-8
Seeding—		
cereals rates and dates, Belle Fourche Experiment Farm....	1039	12
grains, rates, and dates for dry-land and irrigation farming...	1039	12-13, 17- 20, 23-25, 31-32, 35, 39, 50-51, 56
sunflowers, date, rate, and methods.....	1045	10-11
Seedlings, wheat, inoculation with rust spores, experiments.....	1046	5-6, 14-16
Seeds—		
disease-free, importance in cabbage growing.....	1029	23-25
testing to insure against loss from seed failure.....	1043	14
Seepage, return from irrigation, Colorado, amount and uses.....	1026	10-12, 69, 83
Self-service—		
plan for retailing food products, bulletin by F. E. Chaffee and McFall Kerbey.....	1044	1-52
retailing of food products, advantages and disadvantages.....	1044	2-13
Selling—		
food products at retail, self-service plan, bulletin by F. E. Chaffee and McFall Kerbey.....	1044	1-52
SENN, NICHOLAS, citation on value of recreation for health.....	1049	10-11
SHAW, R. H., work on sunflower composition.....	1045	14-15
Sheep—		
feeding, sunflower silage, experiments and results.....	1045	27-29
mountain, enumeration and value.....	1049	24, 25
SHEETS, E. W., and R. H. TUCKWILLER, bulletin on "Effect of winter rations on pasture gains of calves".....	1042	1-15
<i>Shorea</i> spp., occurrence, etc.....	1050	11-12
Shorebirds, protection, hunting regulations.....	1049	27-28
Shrinkage, food products, considerations in retail business.....	1044	43-49
Sicily, source of supply of <i>Apanteles melanoscelus</i> and work there.	1028	14-16
Silage—		
composition, comparison of sunflower, corn, and sorghum....	1045	20-21
corn, feed value for calves.....	1042	7-11
Robertson mixture, tests.....	1045	3-4
sunflower—		
seed value, palatability, color, odor, acidity, etc.....	1045	19-29
use, bulletin by H. N. Vinall.....	1045	1-32
yields, comparison with corn and sorgo.....	1045	17-19
use on ranges.....	1031	71
Silos—		
filling with sunflowers, caution.....	1045	15-17
strengthening with iron bands.....	1045	17

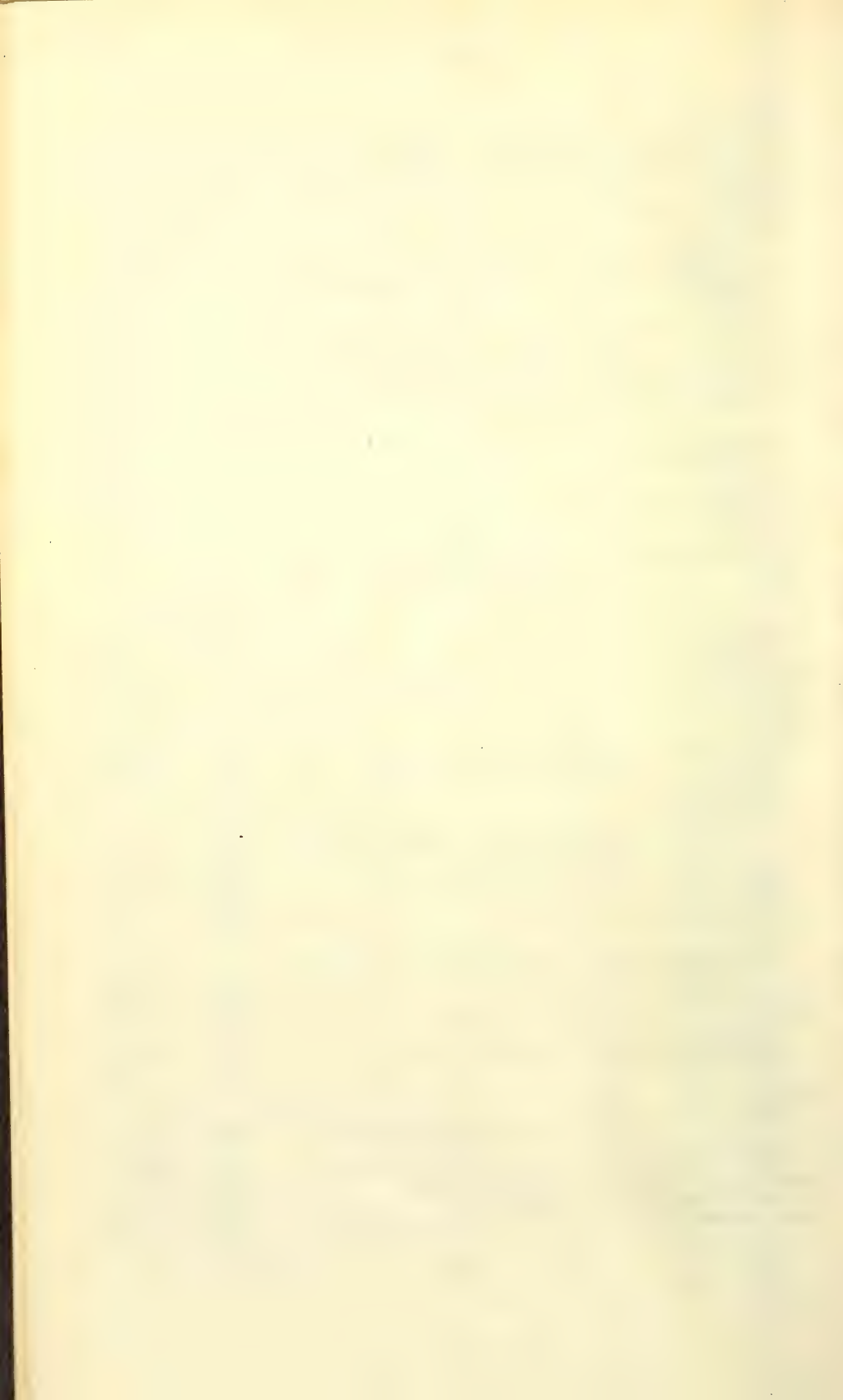
	Bulletin No.	Page.
Sirup, sweet potato, manufacture.....	1041	6, 33
Smut, citrus, cause by citrophilus mealybug.....	1040	3
Soapweed, feeding to cows on range.....	1031	69-70
Sodium—		
carbonate and bicarbonate, timber preservation experiments.....	1037	35-36
fluorid, timber preservation experiments.....	1037	36-37
sulphate, spray for avocado red spider, experiment.....	1035	12
Soil, Pierre clay, nature and occurrence in South Dakota.....	1039	4
Soiling crop, sunflowers, value.....	1045	29
Soils, Colorado, Cache la Poudre Valley, descriptions.....	1026	5-6
Sorghums, grain, growing—		
experiments, Belle Fourche Farm.....	1039	40-41, 71
on dry land, experiments in South Dakota.....	1039	40-41
Sorgo, silage yields, comparison with sunflower.....	1045	18
South—		
agricultural problems, business analysis of farms in southern Georgia.....	1034	3-97
Dakota—		
Belle Fourche Experiment Farm, climatic conditions....	1039	4-11
Custer County game refuge, description and work.....	1049	47
hail insurance on crops.....	1043	16
loan of State funds to farmers.....	1047	23
Newell, climatic conditions, 1908-1919.....	1039	5-11, 70
Newell, experiments with cereals at Belle Fourche Experiment Farm, bulletin by John H. Martin.....	1039	1-72
Wind Cave National Park, purchase and cost.....	1049	45, 46
Southwest, range and cattle management during drought conditions.....	1031	4-84
Spelt, growing in South Dakota, experiments.....	1039	36, 60
Spider, red avocado—		
bulletin by G. F. Mozette.....	1035	1-15
economic importance.....	1035	1-2
life history and biological data.....	1035	4-9
nature of injury by, host plants, distribution, etc.....	1034	2-4
Spike disease—		
description, occurrence, etc., studies.....	1038	7-8
pecan tree, description.....	1038	7-8
Spinning, tests of sea-island and Meade cottons.....	1030	20-22, 24
Spoilage, grocery stock in self-service stores.....	1044	38-39
Spokes, vehicle, treatment of green timber for prevention of sap-stain and mold.....	1037	38-45
Spraying—		
apparatus—		
description.....	1032	28-34, 35-37
for avocado groves.....	1035	13
avocado red spider, experiments.....	1035	11-13
citrus orchards for control of mealybugs.....	1040	13-15, 16, 18
cranberry bogs for control of blackhead fireworm.....	1032	34-41
Sprays—		
cranberry, formulas and use.....	1032	22-28, 33, 34-35, 39-41
mealybug, control on citrus, formulas, and cost.....	1040	13-16, 18
poisonous—		
metal deposits on fruits and vegetables.....	1027	18-49
residues on fruits and vegetables, investigations.....	1027	1-49
Stains—		
chemical, of wood, description, causes, and injuries.....	1037	4-6
fungus, source in sap-stain fungi in woods.....	1037	6-10
Starch—		
content, sweet-potato, variation.....	1041	5
sweet-potato, manufacture.....	1041	6, 33
State funds, farm mortgage loans, systems.....	1047	5
Steaming, lumber, for fungi control, experiments.....	1037	28-32, 51

	Bulletin No.	Page.
Steam-rust, wheat, epidemics, note.....	1046	4
<i>Stilpnotia salicis</i> , host of gipsy-moth parasite.....	1028	12-13
<i>Stipa comata</i> , occurrence in South Dakota.....	1039	4
Stores, self-service, types.....	1044	2-4
Sulphur dust, spray for avocado red spider, experiment.....	1035	11-13
Sunflower—		
rust-resistant, breeding work in Russia.....	1045	30
silage—		
crop, bulletin by H. N. Vinall.....	1045	1-32
feed value, palatability, color, odor, acidity, etc.....	1045	19-29
varieties, description of seed, yields, etc.....	1045	7-9
Sunflowers—		
composition at various stages of growth.....	1045	14
cutting, time and methods.....	1045	13-15
growing—		
for silage.....	1045	9-15
in United States, tests and experiments.....	1045	2-9
insect enemies.....	1045	31
resistance to frost.....	1045	5
seeding, date, method, and rate.....	1045	10-11
soiling crop.....	1045	29
value in semiarid regions.....	1045	5-7
Susquehanna Flats, public hunting grounds, regulations.....	1049	29-30
Sweet potato—		
food value and uses.....	1041	1-3
growth habits, food value, economic importance, etc.....	1041	1-3
Sweet potatoes—		
canned—		
consistency of varieties.....	1041	16-23
pack of 1920.....	1041	1
canning quality of different varieties, study, bulletin by C. A. Magoon and C. W. Culpepper.....	1041	1-34
chemical composition.....	1041	3-6
discoloration in canning.....	1041	15-16
<i>Swietenia</i> spp. See Mahogany.		
<i>Tabebuia donnell-smithii</i> , identification key and description.....	1050	4, 16
Tangle, species, occurrence, etc.....	1050	11-12
Tar—		
coal—		
production, apparatus used, and description.....	1036	11-16
production in 1904-1917.....	1036	18
coke-oven, production, 1909.....	1036	23
gas-house, production, 1908.....	1036	23
use as creosote diluent, properties, value, etc.....	1036	79-83
water-gas—		
production.....	1036	18, 23
source and production method.....	1036	16-18
use with zinc chloride, specifications.....	1036	104-105
Tars—		
coal, sources and nature.....	1036	4-5
coke-oven, specific gravity and carbon content.....	1036	23-25
composition and manufacture.....	1036	7-18
distillation, apparatus and methods.....	1036	27-34
oil, sources and nature.....	1036	5-6
Tea-seed oil, digestibility, experiments.....	1033	6-7
Tenures, farm lands, southern Georgia, comparison of white and colored operators.....	1034	8-97
<i>Tetranychus yothersi</i> . See Spider, red, on avocado.		
Thievery, danger in self-service stores, losses and preventive measures.....	1044	11-13, 31-33
Thrips—		
black, enemy of avocado red spider.....	1035	10
six-spotted, enemy of avocado red spider.....	1035	9
Tillage, preparation of irrigated land for spring grains.....	1039	69-70

	Bulletin No.	Page.
Timber—		
cutting—		
and handling for vehicle stock.....	1037	21-25
effect on fungi control.....	1037	21-22
green, mill storage or handling in transit.....	1037	49-50
preservatives, for fungi control, experiments.....	1037	32-48
Tobacco—		
losses from specified causes in various localities, 1909-1918...	1043	6, 8, 11
mosaic disease, symptoms.....	1038	8
Tobosa grass, value on New Mexico pastures.....	1031	9, 10, 24-25, 33
Tomatoes, sprayed, poisonous residue at picking time, investigations.....	1027	24, 48
Toon, identification key and description.....	1050	3, 7-8
Transportation, vehicle stock, handling in transit.....	1037	23-32
Tree, banding for control of citrophilus mealybug.....	1040	11-13, 16
Truck, crop area and requirements in south Georgia.....	1034	16
TUCKWILLER, R. H., and E. W. SHEETS, bulletin on "Effect of winter rations on pasture gains of calves".....	1042	1-15
TURNER, C. T., range rights to Jornada Range Reserve.....	1031	10-11
Union Colony, development of irrigation in Colorado.....	1026	1, 3
VALGREN V. N.—		
and ELMER ENGELBERT—		
bulletin on "Farm mortgage loans by banks, insurance companies, and other agencies".....	1047	1-23
bulletin on "Bank loans to farmers on personal and collateral security".....	1048	1-26
bulletin on "Crop insurance: Risks, losses, and principles of protection".....	1043	1-27
Vegetables—		
handling in self-service stores.....	1044	35-39
sprayed, poisonous residue at harvest time.....	1027	24-25, 48-49
Vehicle stock, control of sap-stain, mold, and decay in green wood, bulletin by Nathaniel O. Howard.....	1037	1-55
Ventilation, lumber cars, need.....	1035	23-24
Vermont—		
deer—		
killing, 1897-1920, records.....	1049	19, 38
reintroduction and conservation prior to 1897.....	1049	37-38
game value, estimate by State officials.....	1049	14
VINALL, H. N., bulletin on "The sunflower as a silage crop".....	1045	1-32
Virginia, game killing, records in 1920.....	1049	20-22
Vitamin A, occurrence in codliver oil.....	1033	3, 4
WAITE, M. B., W. D. LYNCH, C. C. McDONNELL, J. K. HAYWOOD, and A. L. QUAINANCE, bulletin on "Poisonous metals on sprayed fruits and vegetables".....	1027	1-66
WALKER, J. C., bulletin on "Seed treatment and rainfall in relation to control of cabbage blackleg".....	1029	1-27
Wardens, game, cost and organization of service.....	1049	44-45
Washington, cranberry industry, and occurrence of blackhead fireworm.....	1032	2-6
Water—		
irrigation, exchange practice in Colorado.....	1026	12-13
range, development, and distribution.....	1031	52, 67
rights, Colorado, Cache la Poudre Valley canals, comparison..	1026	13-19
Waterfowl, distribution, sale restrictions, numbers killed, and estimated value.....	1049	7-9
Water-gas tar, source and production method.....	1036	16-18
See also Tar, water-gas.		
Watermelon-seed oil, digestibility, experiments.....	1033	7-8
Weeds, western South Dakota, kind and abundance.....	1039	4-5
West Virginia Experiment Station—		
calf-feeding experiments.....	1042	3-15
work on sunflower silage.....	1045	10, 12, 14, 22, 23

Wheat—

	Bulletin No.	Page.
growing—		
on dry land, experiments in South Dakota.....	1039	13-27
under irrigation, experiments in South Dakota.....	1039	46-52
incubation with <i>Puccinia graminis tritici</i> , experiments, re-		
sults.....	1046	4-24
irrigation in Colorado, 1916, 1917.....	1026	63-64, 84
Kanred—		
agronomic value.....	1046	26-27
varieties resistant to rust, experiments.....	1046	24-26
losses from specified causes in various localities, 1909-1918...	1043	6, 8, 10
rust-resistance—		
experiments with varieties.....	1046	{ 8-13, 17-23
in winter varieties, bulletin by Leo E. Melchers and John		
H. Parker.....	1046	1-32
rust-resistant varieties, studies, historical notes, etc.....	1045	2-32
seeding dates and rates, Belle Fourche Farm.....	1039	20-26, 70-71
seeding rates and dates, dry-land and irrigation farming,		
South Dakota.....	1039	{ 12, 17-19, 23-24, 50-51
varieties resistant to leaf rust.....	1046	26
Wheat-grass, western, occurrence and importance in South Da-		
kota.....	1039	4
Wheats, resistance to rust, literature concerning.....	1046	2-3, 30-32
Wind, velocity at Belle Fourche Farm, April-September, 1908-		
1919.....	1039	9
Winds, hot, losses caused by, 1909-1918.....	1043	{ 6, 7, 8, 9, 10, 11
Wintering, calves, effect of rations on pasture gains, bulletin by		
E. W. Sheets and R. H. Tuckwiller.....	1042	1-15
Wisconsin, cabbage seeds, testing for blackleg infection.....	1029	18-23
Woglum, R. S., and A. D. BORDEN, bulletin on "Control of the		
citrophilus mealybug".....	1040	1-20
Wood—		
chemical treatment for fungi control.....	1037	32-48, 51
green, chemical treatment for control of sap-stain and mold..	1037	32-41
preservative treatment, importance of industry.....	1036	3
preservatives—		
bibliography.....	1036	112-114
coal-tar and water-gas tar, properties and testing methods,		
bulletin by Ernest Bateman.....	1036	1-114
tar creosotes, properties and testing.....	1036	3-111
protection by oil solutions, theory and mechanism.....	1036	84-86
stained or molded, durability.....	1037	17
treating plants, creosotes used.....	1036	22
Woods—		
green, control of sap-stain, mold and decay in vehicle stock,		
bulletin by Nathaniel O. Howard.....	1037	1-55
susceptibility to sap-stain fungi.....	1037	10-11, 51
WRIGHT, P. A., work on sunflower composition.....	1045	14-15
Wyoming—		
Elk Refuge, Jackson Hole, purchase and cost.....	1049	45, 46
Teton Game Reservation, location and boundaries.....	1049	32
Yellow—		
Jersey sweet potato, description, canning quality, etc.....	1041	{ 8, 11, 29, 30
Strasburg sweet potato, description, canning value, etc.....	1041	{ 8, 11, 13, 29, 30
Yellows, peach, causes, symptoms, and transmission.....	1038	6-7
Yellowstone National Park, purchase and cost.....	1049	46
Yields, crops in south Georgia.....	1034	17-21



UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1026



Contribution from the Bureau of Public Roads
THOS. H. MACDONALD, Chief

Washington, D. C.



May 16, 1922

IRRIGATION IN NORTHERN COLORADO.

By ROBERT G. HEMPHILL, *Irrigation Engineer.*

CONTENTS.

	Page.		Page.
Introduction	1	Water rights	13
Cache la Poudre Valley	2	Distribution from river	19
Meteorology	3	Duty of the river	24
Soils	5	Canal systems	26
Water resources	6	Gross duty for canals	42
Seepage return	10	Farm irrigation	51
Drainage conditions	12	Reservoirs	69
Exchange of water	12	Summary and conclusions.	79

INTRODUCTION.

Prior to the establishment of the Union Colony at Greeley, Colo., in 1870, only a few primitive attempts at irrigation farming had been made along the route of the Overland Trail in that State. The small acreage of less than 1,000 acres which was then irrigated for the purpose of raising native hay, vegetables, and grain for the mining camps has increased in the half century which has since elapsed to over 3,000,000 acres, yielding an annual revenue at current prices of over \$100,000,000. This great increase in acreage has carried with it a corresponding development in irrigation practice and in the customs and laws relating to irrigation. In fact, Colorado, while maintaining a ranking in irrigation development second only to that of California, has established laws and customs and standardized practice to such an extent that the people of the State have become in many respects the leaders in such development throughout the Rocky Mountain region. In the aridity of its climate, elevation above sea level, topography, soils, and crops Colorado bears a close resemblance to several neighboring mountain States. It is not surprising, therefore, to find that the methods of preparing land and applying water as well as the laws and administrative systems of the State have been adopted by other States having somewhat similar physical conditions. The results of an irrigation investiga-

tion carried on for a number of years in the valley of the Cache la Poudre River in northern Colorado are herein presented in the hope that they will afford an opportunity for other communities possessing less experience to benefit by the principles and practice so successfully worked out in the Poudre River basin.

The investigation was carried on under a cooperative agreement between the Agricultural Experiment Station of Colorado and the Bureau of Public Roads, each party contributing equal amounts to the undertaking. At first the investigation was in direct charge of V. M. Cone, irrigation engineer, who, under the general direction and supervision of Samuel Fortier, Chief of the Division of Irrigation Investigations, planned and carried out the work during the years 1916 and 1917. Mr. Cone resigned to enter private practice in February, 1918, and Ralph L. Parshall succeeded him as the representative of the bureau in Colorado. Since the writer, however, had been intimately connected with the investigation from the beginning, it fell to his lot to complete the work and write the report.

CACHE LA POUDE VALLEY.

The Cache la Poudre River drains an area of approximately 1,900 square miles in north-central Colorado. The main stream heads in Chambers Lake, a few miles east of the crest of the Medicine Bow Range, and flows in a fairly straight line to its junction with the South Platte River, 60 miles southeast. With its tributaries it drains slopes of the Laramie, Medicine Bow, and Snowy Mountains. About 30 miles east of Chambers Lake the river breaks through the last line of foothills and flows out on the plains. This line of foothills forms a natural division and breaks the basin into two distinct parts. West of the foothills the country is all rough and mountainous and lies at an altitude of from 6,000 to 14,000 feet. Irrigation in this section of the basin is confined almost entirely to forage crops in narrow strips along the streams. East of the foothills the valley proper rarely exceeds a mile or two in width and is 50 to 100 feet below the level of the adjacent land. In this section, and south of the river, the bluffs are rather abrupt and are only a short distance from the divide between the Cache la Poudre and Big Thompson basins, thus limiting irrigation to the river bottoms and a small area of bench land southwest of Fort Collins.

North of the river a rolling prairie, rising gradually from the first bench, extends northward to the Wyoming line, and in this section are located the larger canals and at least 80 per cent of the irrigated land in the basin. The altitude of the eastern division of the basin ranges from 4,500 to 5,500 feet.

In 1870 occurred two events of great importance in the development of the valley. The first was the completion of the Denver Pacific Railroad from Cheyenne to Denver, which afforded a safe and quick means of travel from the East and solved, to a great extent, the problem of supplies. The second was the establishment of the Union Colony in the vicinity of the present town of Greeley.

The first work of this colony was the construction of the Greeley Canal No. 3 to water the town site and the lands adjoining.¹ In the fall of 1870 work on the Greeley Canal No. 2 was started, and water was carried in the canal the following spring. The Greeley Canal No. 2 is notable for the fact that it is the first large canal built by community effort in Colorado and also the first built to water extensive areas of bench land. Mistakes were made in the design and construction of these canals and the cost was many times the estimated amount, but the colonists kept fighting against disheartening odds and were finally rewarded by success.

The success of the Greeley colony in canal building was such that construction by corporations or community effort soon almost entirely supplanted individual effort, and by 1882 practically all the large canals of the valley had been built. Since 1882 the development has consisted of extensions of canals already constructed, the construction of ditches to bring water across from other drainage basins, and the building of the reservoir systems of the valley made necessary by the diversification of crops to include those requiring late irrigation.

METEOROLOGY.

Meteorological records have been taken at the State Agricultural College at Fort Collins for many years and are complete beginning with 1887. (Fig. 1.) While there is a slight variation in climatic conditions over the valley proper, due to a gradual transition from a plains to a foothill climate, this difference is so small as to be of no significance so far as irrigation is concerned, and the Fort Collins records may be taken as representative of the whole valley. They show the chief characteristics of the climate to be a light rainfall, with correspondingly few stormy days and much sunshine, a wide range in daily and seasonal temperature, low relative humidity, a moderately high wind movement, and a comparatively low rate of evaporation. In Table 1 is given a summary of 31 years of the Fort Collins records.

¹ See Second Biennial Report, State Engineer of Colorado, 1883-84, by Col. E. S. Nettleton. Also History of Greeley and the Union Colony, by David Boyd. Also History of Larimer County, by Ansel Watrous. Also University of Colorado Historical Collections: The Union Colony at Greeley, 1869-1871, by James F. Willard.

TABLE 1.—*Summary of meteorological records at Fort Collins, Colo., 1887-1917.*^a

Month.	Rainfall (inches).			Temperature (°F.).			Wind (miles per hour).			Relative humidity (per cent saturation), mean.	Evaporation (inches). ^b		
	Mean.	Monthly mean.		Mean.	Absolute maximum.	Absolute minimum.	Mean.	Monthly mean.			Mean.	Maximum monthly mean.	Minimum monthly mean.
		Maximum.	Minimum.					Maximum.	Minimum.				
January.....	0.35	2.32	0.01	25.9	71.0	-31.4	6.4	10.1	4.0	71.3	1.23	2.64	0.68
February.....	.62	1.65	.03	26.7	70.0	-38.4	6.9	10.4	4.4	72.5	1.45	3.23	.58
March.....	1.05	3.35.	.00	35.7	80.3	-24.6	7.9	11.9	4.7	67.1	2.63	4.60	.57
April.....	2.16	10.56	.05	46.1	91.0	5.1	8.4	12.3	5.9	59.7	4.21	6.17	2.24
May.....	3.06	7.47	.60	53.9	90.0	12.1	6.9	10.9	4.7	63.4	4.65	6.63	3.49
June.....	1.48	3.65	.03	63.1	94.2	31.2	6.0	9.6	4.5	63.9	5.42	7.70	3.97
July.....	1.82	4.95	.17	68.1	99.9	36.0	4.8	7.0	3.1	66.8	5.59	7.32	4.26
August.....	1.23	3.14	.16	67.2	99.6	31.7	4.7	6.4	3.1	67.2	5.07	6.57	3.79
September.....	1.29	3.08	.00	59.2	95.0	22.0	5.1	7.2	3.5	67.2	4.30	5.57	3.14
October.....	1.12	3.23	.....	47.7	88.0	- 8.0	5.7	9.1	3.3	67.9	3.28	4.64	2.17
November.....	.40	1.80	.....	36.0	78.0	-21.1	6.0	9.4	2.8	69.8	1.56	2.81	.62
December.....	.46	4.08	.....	28.0	68.0	-31.0	6.5	10.2	3.4	72.3	1.17	1.88	.26
Year.....	15.04	22.49	7.11	46.5	99.9	-38.4	6.3	9.3	4.7	67.4	40.59	47.30	34.24

^a All meteorological records pertaining to Fort Collins were taken from Colorado Experiment Station Bulletin No. 245. Colorado Climatology, by Robert E. Trimble, 1918.

^b From tanks 3 by 3 feet deep. Water surface about 2 inches above ground.

Approximately two-thirds of the rainfall comes during the growing season, from April 15 to September 15. An average of 74 days of the year shows precipitation, mostly in the form of light showers and snows, though rains of more than 0.5 inch usually occur several times during the season. Heavy local rains or cloudbursts occasionally do some damage to crops and canals, but in general they are rather a benefit, as they flood the streams and afford additional water for irrigation and storage. At Greeley² the average rainfall is about 2 inches less than at Fort Collins, but the seasonal distribution is about the same. In the mountainous section of the Cache la Poudre drainage area the rainfall is heavier and averages perhaps 22 inches annually. There is a rather notable range of temperature in the valley. At Greeley temperatures of 103° above and 45° below zero have been recorded, giving an absolute range at that point of 148°. At Fort Collins the mean temperatures for January and for July differ by 40°, and the daily range is approximately 30°, but warm chinooks from the west or cold waves from the north often produce a change of as much as 40° within 2 or 3 hours. In general, the extremes of temperature last only a short time, and the impression of the climate which remains is one of crisp dry air, clear skies, and warm sunlight. At Fort Collins the average period between killing frosts is 144 days,

² Meteorological records for Greeley were furnished by F. H. Brandenburg, U. S. Weather Bureau, Denver.

or from May 5 to September 26, while at Greeley the period is 9 days longer, from May 1 to October 1.

In spite of low relative humidity and moderately high wind movement, the average annual evaporation from a water surface is comparatively low at Fort Collins. The average for the year is reduced by the small amount for the winter months. During the summer months, when water is held in reservoirs for future irrigation, the evaporation is heavy.

Weather conditions during the period of investigation varied from the average only to a small extent. Figure 1 is given to show the rainfall, temperature, and evaporation at Fort Collins during 1916 and 1917 as compared with the average for a period of 31 years.

SOILS.³

A soil survey including the Cache la Poudre Valley was made in 1904 by the Bureau of Soils, United States Department of Agriculture, and 10 soil types were found and mapped. Those occurring most extensively in the valley were designated as Colorado fine sandy loam, Laurel sandy loam, and Fort Collins loam.

The Colorado fine sandy loam covers a large area north of the river between Fort Collins and Greeley. It is a residual soil, light to dark brown in color, extends to an average depth of about 3 feet, and is underlain by a loam or a heavy fine sandy loam to a depth of 6 feet or more. The silt and clay content increases with the depth. The loose texture of this soil affords good drainage and, except in draws or depressions where seepage comes to the surface, there is

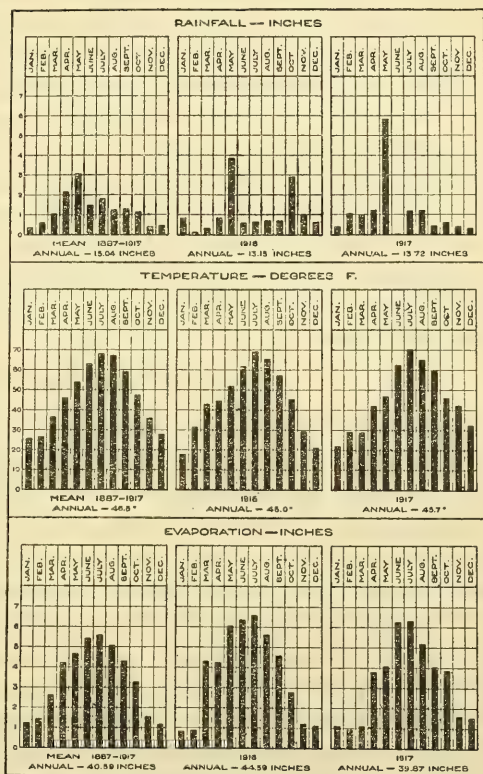


FIG. 1.—Meteorological conditions at Fort Collins during the period of the investigation compared to the average for 31 years.

³ Soil Survey of the Greeley Area, Colorado, by J. Garnett Holmes and N. P. Neill. Field Operations of the Bureau of Soils, 1904.

not enough alkali to injure crops. This soil is especially well adapted to grain, alfalfa, and potatoes.

The Laurel sandy loam is an alluvial soil and occurs in a strip one-half to 1 mile wide in the river bottoms. It ranges in depth from 2 to 5 feet, and is dark brown to black in color. The soil becomes more sandy with depth, passing gradually into coarse sand and water-worn gravel. This soil is not very well drained and the water table is near the surface the greater part of the year. Only small areas, however, are affected by alkali. This soil is particularly well adapted to cabbages, onions, and sugar beets.

The Fort Collins loam occurs in small areas north of Greeley and in the vicinity of Fort Collins. It consists of a reddish to a very dark brown light loam, from 4 inches to 1 foot in thickness, underlain by a layer of heavy loam from 1 to 4 feet in thickness. Below this layer of loam the subsoil grades again into a light loam extending to a depth of 6 feet or more. The soil is very sticky when wet and bakes badly. It is fairly well drained, is affected by alkali in small areas only, and is adapted to fruits, grain, potatoes, alfalfa, and sugar beets.

WATER RESOURCES.

Water for irrigation in the Cache la Poudre Valley is obtained from the river and its tributaries: from supply ditches collecting run-off from the high slopes of the drainage systems of the Grand, Michigan, and Laramie Rivers; from shallow pumped wells; and from seepage from canals, reservoirs, and irrigated lands which returns to the river or its tributary channels.

A station for gaging the river has been maintained since 1884 at the mouth of the canyon, above all canal headings but the North Poudre and Poudre Valley, and because of the permanence of the channel section there the continuous automatic record of stage, the frequent ratings to check the discharge curve, and the length of the period covered, the records of discharge at that point are particularly complete and accurate. As the river is fed principally by melting snow, characteristic marked variations in yearly, seasonal, and daily discharge are to be expected.

The discharge varies from year to year with the fall and winter temperatures and the amount of precipitation on the upper slopes of the basin, the greatest discharge coming after a fall and winter which pack the deep gulches with snow and ice. The annual discharge at the canyon station averages 320,000 acre-feet, but has varied from a minimum of 169,000 acre-feet in 1888 to a maximum of 689,000 acre-feet in 1884.

The wide seasonal variation is due to the spring flood produced by rapid melting of snow in the hills. Its duration and intensity depend on the amount of snow to be melted and the temperature, a continued high temperature producing a rapid rise, a high crest early in the season, and a subsequent rapid fall, and a low temperature producing a more gradual rise and fall with comparatively low and late crest. The average date of the crest is June 10, but it has come as early as May 17 and as late as June 28. The discharge at the crest has varied from a mean of 1,550 second-feet on June 19, 1888, to a mean of 5,800 second-feet on June 23, 1917. The lowest discharge is about 30 second-feet and occurs in winter after severe cold weather has frozen most of the stream.

The daily rise and fall is pronounced only during the spring flood, when alternate freezing and thawing of snow on the high slopes of the basin produce a variation of several hundred second-feet at the gaging station, the maximum recorded being 1,500 second-feet. Sudden floods, due to storms, are common and there are records showing a rise of more than 5 feet in less than 30 minutes, caused by cloud-bursts in narrow branch canyons with steep slopes.

Records of discharge of the river from 1884 to 1917, inclusive, are given in Table 2. During the winter months ice conditions at the gaging station are such that automatic records are of little value, and such as were available were discarded. Estimates of the flow from November to March, inclusive, were furnished by John Armstrong, water commissioner for the stream, who has handled the division of the winter flow for over 25 years. To arrive at the annual discharge, Mr. Armstrong's estimates for the winter months were combined with available figures for other months, and then, if April or October records were partly missing, they were interpolated in the proportion of the percentages shown in the table. The winter flow is so small that this method of estimating could not produce an error of as much as 5 per cent. Data included in the table are from the original records of the Colorado Experiment Station and from reports of the State engineer. In considering this table it should be noted that the North Poudre and Poudre Valley Canals divert about 40,000 acre-feet above the gaging station annually, and that part of the water passing the station is foreign water from other drainage basins.

TABLE 2.—*Discharge of the Cache la Poudre River at gaging station at mouth of canyon.*

Year.	Discharge in second-feet.												Estimated annual discharge in acre-feet.
	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	
1884.....				219	2,536	4,812	2,143	792	305				689,000
1885.....					1,419	2,910	1,860	657	272				478,000
1886.....					1,309	1,872	717	306	185				302,000
1887.....						1,802	737	310	174				
1888.....					489	1,117	421	201	105				169,000
1889.....				113	770	1,339	511	184	69	70			203,000
1890.....				200	1,046	1,281	647	290	103	81			271,000
1891.....				144	1,250	1,833	541	228	138	118			275,000
1892.....					408	1,512	735	209					
1893.....					570	1,802	614	237					
1894.....					1,406	2,063	735	339	164	104			321,000
1895.....					1,191	2,346	1,222	499	220	175			374,000
1896.....					912	1,062	452	274	294	199			219,000
1897.....					1,960	1,728	511	379	166	123			303,000
1898.....				146	656	1,317	455	154	70	61			192,000
1899.....					1,206	2,609	1,452	563	216	156			408,000
1900.....				742	3,095	3,281	674	231	134	108			518,000
1901.....					1,802	2,049	774		135	99			
1902.....				106	1,069	1,291	379	176	166	136			219,000
1903.....					801	2,715	964	282	164	156			337,000
1904.....				161			1,043	328	176				
1905.....				317	1,031	2,707	908	340	158				356,000
1906.....					1,083	1,652	935						
1907.....				119	646	2,777	1,757	473	186				388,000
1908.....				135		1,493	792	766	229				
1909.....				239	703	3,703	1,852	452	331	140			466,000
1910.....				179	780	947	269	128	152	154			176,000
1911.....				69	819	1,707	764	218	173	126			252,000
1912.....				63	785	2,186	1,230	429	212	163			325,000
1913.....					920	1,230	538	265	204	184			229,000
1914.....				215	2,147	2,500	818	335	195	91			403,000
1915.....					591	1,521	700	274	208	116			232,000
1916.....				151	847	1,703	754	397	263	114			274,000
1917.....				134	1,295	3,996	2,050	392	292	111			518,000
Average discharge, sec.-ft.	50	55	55	192	1,147	2,087	911	347	189	127	83	60	320,000
Equivalent discharge, acre-feet	3,070	3,050	3,375	11,405	70,405	123,970	55,920	21,300	11,225	7,795	4,930	3,685	320,130
Per cent..	1.0	0.9	1.1	3.6	22.0	38.7	17.5	6.7	3.5	2.4	1.5	1.1	100.0

¹ The figures in this line are not averages of the preceding figures but were obtained by combining the daily averages for each month. By this method records for only a part of a month which could not be shown as a monthly average could be included in the general average.

Figure 2 shows the discharge of the river from April to September, inclusive, during 1916 and 1917, the period of the investigation, as compared with the average for a period of 34 years. It will be noticed that the discharge for 1916 was very nearly normal, but that for 1917 was far above normal.

The small creeks tributary to the Cache la Poudre River below the canyon furnish only a small percentage of the total water supply of the valley. Rainstorms flood these creeks for a day or two, but ordinarily they are dry or nearly so, except where a flow of a few second-feet is produced by seepage. Records of flow of the more important of these tributaries, together with estimates for the smaller streams, show that the supply from this source is about 40,000 acre-feet in average years, of which 15,000 acre-feet may be classed as

normal run-off and 25,000 acre-feet as returned seepage. The greater part of this flow is intercepted by canals and reservoirs before it reaches the river.

The foreign water turned into the Cache la Poudre River has averaged 35,000 acre-feet for a number of years. The Grand River ditches of the Water Supply & Storage Co. bring over about 11,500 acre-feet from the Grand River drainage area. Ditches of the Water Supply & Storage Co. and the North Poudre Irrigation Co. draw about 3,500 acre-feet from the Michigan River drainage area. The remainder, 20,000 acre-feet, is brought over from the Laramie River drainage area by the Skyline Ditch of the Water Supply & Storage Co., the Greeley-Poudre irrigation district's tunnel, the Sand Creek feeder of the Worster Reservoir, and others. The greater part of this foreign water is diverted by the North Poudre Valley, and the Larimer County Canals.

The Greeley-Poudre district, having no land under irrigation, usually sells the tunnel water to the highest bidder. The record of discharge of the river at the canyon rating station includes all foreign water passing that point.

The amount of water obtained by pumping from wells does not exceed 5,000 acre-feet annually and is generally used late in the

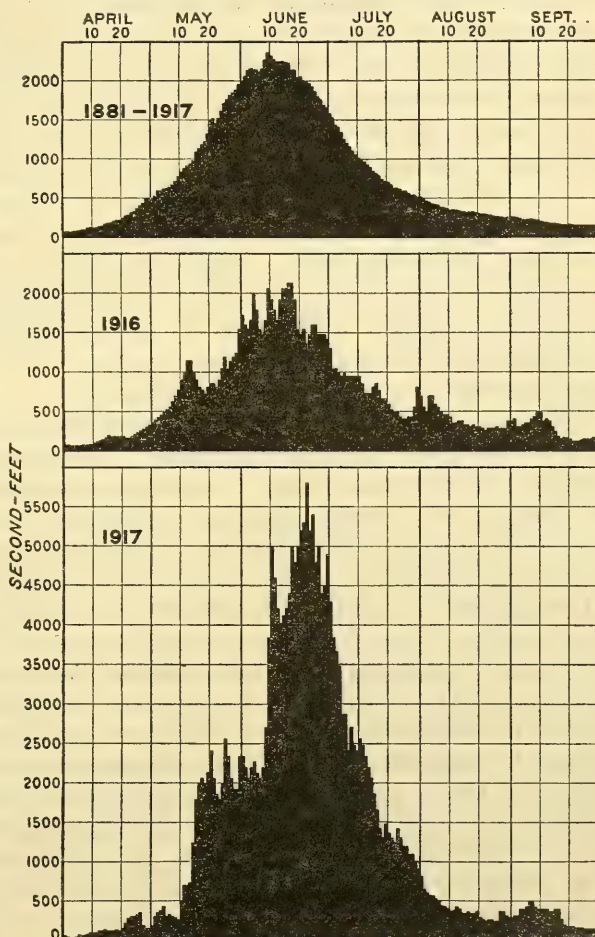


FIG. 2.—Discharge of the Cache la Poudre River at the rating station at the mouth of the canyon during the period of the investigation compared with the average for approximately 35 years.

season instead of reservoir water to provide for an irrigation after canal supplies fail.

The total amount of seepage return to the river, exclusive of that coming through regular channels, is about 110,000 acre-feet annually. During the winter months only the return above the intake of the Cache la Poudre Reservoir may be used, and this is estimated to be about 8,000 acre-feet. During the summer months canals on the lower reaches of the river depend to a considerable extent on this return flow to satisfy their rights, and it is estimated that during these months 51,000 acre-feet are available for their use. Combined, the total available flow for the year is 59,000 acre-feet.

To summarize, the water supply of the valley includes a normal run-off of 340,000 acre-feet in the river and its tributaries, 35,000 acre-feet of foreign water, 5,000 acre-feet pumped from wells, and available seepage to the amount of 84,000 acre-feet, a total supply of 464,000 acre-feet. This supply in the course of time will be increased slightly by pumping and by a greater return of seepage, but any material increase seems improbable.

With the exception of very short periods during high floods, the entire available flow of the stream is taken on rights which have been in existence for years. There is an occasional surplus subject to storage, but because of the uncertainty attaching to it and the probable high cost of developing it, the feasibility of such a supply is highly questionable. The demand on the river in June the month of maximum flow, is close to 120,000 acre-feet,⁴ which is equivalent to an average flow of approximately 2,100 second-feet. From Table 2 it appears that the river has failed to reach that discharge in 18 of the 33 years covered by the records. To produce a surplus of 20,000 to 25,000 acre-feet a discharge of at least 2,500 second-feet would be required during June, and such a discharge occurred in only 9 of the 33 years covered by the records. From this it is clear that any further storage projects would have to depend on a surplus which would be of considerable size only about once in 3 or 4 years. The amount available annually for use from such a supply would be very small and very costly.

SEEPAGE RETURN.

One of the questions of particular interest now in many irrigated valleys is that of seepage return to streams. It is a well-known fact that, with the extension of irrigation, this return has so increased that canals on the lower reaches of the rivers, which once suffered seriously because their rights would not be satisfied, are now plentifully supplied with water. In the Cache la Poudre Valley the effect of the seepage return is very marked. Late in the season it is often the case that the river is dry in several places, yet a number of

⁴ See Tables 7 and 8.

the lower canals may be drawing their full appropriations from the supply developed by seepage return.

Prof. L. G. Carpenter, for a number of years director of the Colorado Experiment Station, made one or more measurements of the Cache la Poudre River each year, for more than 20 years, to determine the seepage return to the stream. These determinations were spot measurements, good only for the conditions at the time of the observation, but the large number of observations and the care with which they were made establishes their dependability. The average of the measurements, made in the spring and fall at low stages of the river, shows a return between the canyon and the mouth of the river of 153 second-feet, which included seepage intercepted by canals near the river.

The rating stations maintained during 1916 and 1917 on the river, its tributaries, and the canals diverting from it, provided continuous records from which the seepage return shown in Table 3 was determined. These figures show the net return to the river from the canyon to the mouth, but do not include seepage entering through the channels of the various tributaries below the canyon. To arrive at these figures the total supply from all sources was determined by adding the discharge of the river at the lower rating station and the discharge of all canals, less the water returned to the river through sluices and wasteways. The supply available from the normal flow of the stream was then obtained by adding the discharges of the North Poudre and Poudre Valley Canals, the river discharge at the canyon station, and the inflow to the river from the tributaries entering below the canyon. The supply available from the normal flow of the stream was then subtracted from the total supply, the difference being the amount of seepage return. Results obtained in this manner will contain a certain amount of run-off from rains and irrigation which reaches the river directly instead of passing through the tributary channels on which measurements were made. The amount is small, however, and may be neglected.

TABLE 3.—*Seepage return to the Cache la Poudre River in 1916 and 1917.*

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Return in 1916 (acre-feet)	4,600	4,150	4,667	6,297	11,328	9,491	13,801	13,324	10,233	11,412	10,615	7,465	.....
Return in 1917 (acre-feet)	6,604	6,094	7,875	7,727	(1)	(1)	14,534	14,322	9,830	8,586	10,186	6,386	.....
Average in acre-feet	5,602	5,122	6,271	7,012	11,328	9,491	14,167	13,823	10,032	9,999	10,400	6,925	110,172
Average in second- feet	91	92	102	118	184	160	231	225	169	163	175	113	152

¹ The figures for May and June, 1917, are omitted on account of their probable inaccuracy. Records at the station near the mouth of the river were interrupted for a week or ten day when the discharge was over 2,000 second-feet. Results obtained by interpolation are subject to too great an error at that stage of the river.

Seepage which reaches the tributaries and then flows into the river is approximately 15,000 acre-feet yearly. There are many other streams of seepage and runoff from irrigated fields which are

intercepted for direct use or for storage. A conservative estimate of the amount of this seepage would be 12,000 acre-feet. Added together, these give a total seepage return for the valley of approximately 137,000 acre-feet annually, which is equivalent to a constant flow of 190 second-feet. The average annual water supply of the valley, exclusive of seepage, is 380,000 acre-feet, and the seepage return as estimated above is slightly over 36 per cent of that supply.⁵

DRAINAGE CONDITIONS.

From the preceding section on seepage return the natural presumption would be that drainage must be one of the important problems of the valley, but such is not the case. As is to be expected in any irrigated area, for many years wet spots have developed, but these spots rarely exceeded 40 to 80 acres in extent and were usually drained as soon as the condition became bad. Because of the rolling topography, the sandy character of the soil, and the many natural channels, the construction of the required small systems of tile drains presented no difficulties. It is estimated that close to 10 per cent of the irrigated land of the valley is underlain by drains. Land needing drainage at present is in scattered spots and in only two instances is there as much as 500 acres in one body.

EXCHANGE OF WATER.

In order to utilize sites which could be developed cheaply and at the same time to save the cost of intake canals, 12 reservoirs of the Cache la Poudre Valley, with an aggregate capacity of about 50,000 acre-feet, were built below the distributing canals of the companies owning them. The problem of making the water stored in these reservoirs available for use in the distributing canals above has been solved by the development of a very complicated system of exchange of water. In 1916, an average year, the operation of the exchange system made available for use on higher land about 55,000 acre-feet of water stored in low reservoirs, or 14 per cent of the total supply used by all the canals of the valley.

The principal exchange system of the valley involves the 4 largest canals, and to understand it clearly a few facts must be kept in mind. Beginning at the lower end of the river and going upstream, the Greeley Canal No. 2, the Larimer and Weld Canal, and the Larimer County Canal of the Water Supply & Storage Co. head in the order named. Next above and diverting from the North Fork is the North Poudre Canal. The principal water rights of these canals stand in the same order of priority, the Greeley Canal No. 2 coming first with an appropriation dating 1870 and the North Poudre Canal coming last with an appropriation dating 1881. Reservoirs No. 5 and No. 6 of the North Poudre Co. are too low to supply directly any land under the canal, and their outlet empties into the Larimer County

⁵ This does not include seepage from Poudre Valley land entering directly into the South Platte.

Canal. With the exception of Black Hollow, the reservoirs of the Water Supply & Storage Co. below the canyon are also low and their outlets are arranged so that water from them may be turned into the Larimer and Weld Canal or the river. Below the Larimer and Weld Canal is the Windsor Reservoir, which has a capacity of 17,000 acre-feet and discharges into the Greeley Canal No. 2. A few of the rights in this reservoir are held under the Greeley Canal No. 2, but the great majority are owned by farmers under the Larimer and Weld Canal. The exchange is operated by taking advantage of all these conditions.

Except during high-flood periods the rights of the Greeley Canal No. 2 may entitle it to practically the entire flow of the North Fork, but instead of allowing this water to flow down the channel of the river to be taken directly by the canal, the water commissioner permits the North Poudre Canal to divert it for use, and directs that an equal amount be turned from the Windsor Reservoir to the Greeley Canal No. 2 when the drop in the river reaches that canal. If, for instance, a flow of 100 second-feet has been taken for 10 days, the North Poudre Co. then owes the Windsor Reservoir 1,985 acre-feet, or 87,000,000 cubic feet, as it is expressed locally, and to secure the debt that amount of water is held in the North Poudre Reservoir No. 6. In other words, Windsor Reservoir water to the amount of 1,985 acre-feet has been transferred upstream for delivery to rights under the Larimer and Weld Canal, and the North Poudre Co. has been able to use in its main canal 1,985 acre-feet of the water stored in its low reservoirs. While channels are available through which the water in Reservoir No. 6 could be delivered direct to the Larimer and Weld Canal, this is never done. Instead, the water is delivered to the Larimer County Canal Co. at any time on demand of the Water Supply & Storage Co., and in exchange this company holds sufficient water in its low reservoirs to deliver 1,985 acre-feet to the Larimer and Weld Canal to supply the demands of the holders of Windsor Reservoir rights. It will be noted that while the Greeley Canal No. 2 has been left undisturbed in its rights, the use of 1,985 acre-feet of its appropriation has served to exchange nearly 6,000 acre-feet of water stored in low reservoirs.

WATER RIGHTS.

The development of irrigation was so rapid in the Cache la Poudre basin that the problem of an equitable division of the water in the stream arose earlier than in any other section of the State. The need became pressing with the construction of large canals in the late seventies, and the efforts of the people of the valley to solve the problem resulted in the inauguration in 1879-1881 of the present system of water administration. The first general adjudication of water rights in the Cache la Poudre and its tributaries was held immediately after, and with few exceptions the rights decreed then

are now in force and unimpaired. In Table 4 the rights of the principal canals of the valley are listed, with notes to show how they were acquired or changed. Ninety per cent of the direct irrigation rights of the stream are included, those omitted being chiefly rights of small ditches above the canyon or at the head of tributaries entering below the canyon.

TABLE 4.—*Water rights of the principal canals of the Cache la Poudre Valley.*

	Priority number.	Date.	Amount (sec.-ft.).	Remarks.
North Poudre Canal.....	2	June 1, 1861	0.72	Transferred from Watrous, Whedbee & Second Ditch.
	17	Apr. 15, 1866	4.77	Transferred from Taylor and Gill Ditch.
	19	July 1, 1866	2.16	Transferred from Watrous, Whedbee & Second Ditch.
	29	June 1, 1868	2.16	Do.
	40	May 1, 1871	4.00	Transferred from Wm. Calloway Ditch No. 1; use limited to certain land.
	52	July 20, 1872	15.00	Transferred from Arthur Ditch.
	60	July 1, 1873	7.20	Transferred from Aquila Morgan Ditch.
	¹ 61	do.....	9.38	Transferred from Brown Ditch No. 1.
	63	Aug. 15, 1873	3.32	Transferred from Brown Ditch No. 2.
	66	Sept. 1, 1873	11.00	Transferred from Arthur Ditch.
	69	May 15, 1874	3.32	Transferred from Brown Ditch No. 3.
	77	May 1, 1875	6.72	Transferred from Brown Ditch No. 4.
	79	Jan. 1, 1876	6.72	Transferred from Brown Ditch No. 5.
	80	June 1, 1876	6.72	Transferred from Brown Ditch No. 6.
	82	June 1, 1877	2.85	Transferred from Brown Ditch No. 7.
	97	Feb. 1, 1880	315.00	Original appropriation; by court decree subsequently made inferior to priority No. 100 of the Larimer County Canal.
Total.....			401.04	
Poudre Valley Canal.....	28	Mar. 15, 1868	1.63	Transferred from Canyon Ditch.
	56	Mar. 20, 1873	24.44	Do.
Total.....			26.07	
Pleasant Valley and Lake Canal.	4	Sept. 1, 1861	10.97	Original appropriation.
	11	June 10, 1864	29.63	
	51	July 10, 1872	16.50	
	92	Aug. 18, 1879	80.83	
Total.....			137.93	
Larimer County Canal.....	5	Mar. 1, 1862	10.77	Transferred from Pioneer Ditch.
	12	Sept. 15, 1864	13.89	Do.
	23	Mar. 15, 1868	4.66	Transferred from Canyon Ditch.
	56	Mar. 20, 1873	4.00	Do.
	84	Apr. 1, 1878	7.23	Appropriation of Smith Ditch acquired with right of way.
	100	Apr. 25, 1881	463.00	Original appropriation; by court decree subsequently made superior to priority No. 97 of the North Poudre Canal.
Total.....			503.55	
Jackson Ditch.....	3	June 10, 1861	11.67	Original appropriation.
	36	Oct. 21, 1870	14.42	
	67	Sept. 15, 1873	12.13	
	91	July 15, 1879	12.70	
Total.....			50.92	
Little Cache la Poudre Ditch.	31	May 1, 1869	62.08	Do.
	58	May 1, 1873	20.42	
Total.....			82.50	
Taylor and Gill Ditch.....	17	Apr. 15, 1866	12.15	Of the original appropriation of 18.48 second-feet, 4.77 second-feet transferred to North Poudre Canal and 1.56 second-feet returned to river to protect it from loss on account of transfer.
Larimer County Canal No. 2.	14	May 1, 1865	4.00	Transferred from John R. Brown Ditch.
	57	Apr. 1, 1873	175.00	Original appropriation.
Total.....			179.00	

¹ The appropriations of the Brown Ditches are not owned by the company but are carried in the canal under a perpetual contract.

TABLE 4.—*Water rights of the principal canals of the Cache la Poudre Valley—*
Continued.

	Priority number.	Date.	Amount (sec.-ft.).	Remarks.
New Mercer Canal	25	Oct. 1, 1867	7.03	Transferred from Josh Ames Ditch (in litigation). Original appropriation.
	33	Sept. 1, 1869	4.17	
	47	Oct. 10, 1871	8.33	
	49	July 1, 1872	15.00	
	99	Feb. 15, 1880	136.00	
Total.....			170.53	
Arthur Ditch.....	2	June 1, 1861	.72	Transferred from Watrous, Whedbee & Second Ditch. Do. Do. Original appropriation. Remainder of appropriation of 33.33 second-feet transferred to North Poudre Canal. Remainder of appropriation of 63.28 second-feet transferred to North Poudre Canal.
	19	July 1, 1866	2.16	
	29	June 1, 1868	2.16	
	32	June 1, 1869	1.67	
	38	Apr. 1, 1871	31.67	
	52	July 20, 1872	18.33	
	66	Sept. 1, 1873	52.28	
Total.....			108.99	
Larimer and Weld Canal....	10	June 1, 1864	3.00	Original appropriation of No. 10 ditch. Original appropriation of Larimer and Weld Canal.
	21	Apr. 1, 1867	16.67	
	45	Sept. 20, 1871	75.00	
	73	Jan. 15, 1875	54.33	
	88	Sept. —, 1878	571.00	
Total.....			720.00	
Josh Ames Ditch.....	25	Oct. 1, 1867	17.97	Remainder of appropriation of 35.92 second-feet returned to river by courts or transferred (in litigation). Original appropriation. Do. Do.
Lake Canal.....	54	Nov. 1, 1872	158.35	
Coy Ditch.....	13	Apr. 10, 1865	31.63	
Chaffee Ditch.....	48	Mar. 10, 1872	22.38	
Boxelder Ditch.....	15	Mar. 1, 1866	32.50	Do.
	23	May 25, 1867	8.33	
	30	July 1, 1868	11.93	
Total.....			52.76	
Greeley Canal No. 2.....	37	Oct. 25, 1870	110.00	Do.
	44	Sept. 15, 1871	170.00	
	72	Nov. 10, 1874	184.00	
	83	Sept. 15, 1877	121.00	
Total.....			585.00	
Whitney Ditch.....	7	Sept. 1, 1862	48.23	Do.
	43	Sept. 10, 1871	12.95	
Total.....			61.18	
B. H. Eaton Ditch.....	9	Apr. 1, 1864	29.10	Do.
	18	June 1, 1866	3.33	
	53	July 25, 1872	9.27	
Total.....			41.70	
Jones Ditch.....	24	Sept. 1, 1867	15.52	Do.
Greeley Canal No. 3.....	35	Apr. 1, 1870	52.00	Do.
	46	Oct. 1, 1871	41.00	
	50	July 15, 1872	63.13	
	59	May 15, 1873	16.66	
Total.....			172.79	
Boyd and Freeman Ditch....	6	Mar. 15, 1862	66.05	Do.
	20	July 15, 1866	9.00	
	62	Aug. 1, 1873	24.23	
Total.....			99.28	
Ogilvy Ditch.....		July 21, 1881	57.60	Original appropriation; junior to all rights of the first adjudication.

The court, in arriving at the decree of 1882, had little definite information regarding the water requirements of various soils and crops to guide it, nor were there available any accurate measurements of the capacities of the canals, whose rights were being adjudicated; and it was human for the claimants to give themselves the benefit of the doubt. The result was that many of the canals were given decrees for appropriations in excess of their capacities or of their requirements for years to come. Enlargement and extension of the area irrigated by most of these canals have brought them to the point where their capacities, amounts diverted, and amounts used are well balanced. In the case of others no enlargement has taken place, but part of the excess appropriation has been transferred to other canals. Still others retain their excessive rights, but have insufficient capacity to carry them or else serve such a small acreage that only a part of the appropriation can be used properly.

In Table 5 a comparison is made between the total rights of each canal and its capacity, as shown by its maximum discharge during 1916 and 1917. The maximum discharges noted, which covered periods of at least two hours, are believed to represent with fair accuracy the maximum capacities of the canals. The fact that records were being taken by disinterested agencies seemed to appeal to some canal men as affording an opportunity of establishing a record of the capacity of their canals. In 1917 a number were crowded to their limit for short or long periods when the water might more profitably have been allowed to pass on down the river. In 1916 conditions were different and maximum discharges were carried that year because the water was actually needed. If the Poudre Valley Canal be omitted, which is warranted by the fact that its capacity is primarily for carrying water for storage, the canals show an average capacity nearly 10 per cent in excess of their rights.

TABLE 5.—*Comparison between water rights and capacities of canals of the Cache la Poudre Valley.*

	Total rights (sec-ond-feet).	Max-imum dis-charge (sec-ond-feet).	Ratio (per cent.)		Total rights (sec-ond-feet).	Max-imum dis-charge (sec-ond-feet).	Ratio (per cent.)
North Poudre Canal.....	401	201	50	Larimer and Weld Canal.....	720	754	105
Poudre Valley Canal.....	26	297	1,142	Josh Ames Ditch.....	18	120	111
Pleasant Valley and Lake Canal.....	138	157	114	Lake Canal.....	158	185	117
Larimer County Canal....	504	597	118	Coy Ditch.....	32	118	56
Jackson Ditch.....	51	52	102	Chaffee Ditch.....	22	121	95
Little Cache la Poudre Ditch.....	82	137	167	Boxelder Ditch.....	53	121	228
Taylor and Gill Ditch.....	12	22	183	Greeley Canal No. 2.....	585	558	95
Larimer County Canal No. 2.....	179	186	104	Whitney Ditch.....	61	61	100
New Mercer Canal.....	171	112	65	B. H. Eaton Ditch.....	42	123	55
Arthur Ditch.....	109	51	47	Jones Ditch.....	16	129	181
				Greeley Canal No. 3.....	173	102	59
				Boyd and Freeman Ditch.....	99	124	24
				Ogilvy Ditch.....	58	122	210

¹ These figures are based on daily gage readings. The remainder are from continuous automatic records of gage heights.

So many varying factors determine the time any right may draw from the river that it is impossible to make any statement in this regard which will not be inaccurate under certain combinations of circumstances. It is generally true, however, that appropriations up to and including priority No. 25 are satisfied throughout the season, while the original appropriations of the Larimer County and North Poudre Canals, priorities No. 100 and No. 97, draw only from 1 to 3 weeks during June. Between these two extremes are a large number of appropriations which fail chiefly in August. Several conditions tend to increase the length of time the later appropriations may draw. Usually there is plenty of rain in the early spring to get the crops started and the older appropriators call for their water only when it is really needed, thus permitting the later rights to draw the available supply. Later in the season some of the oldest appropriators may cut back to the river a part of their supply, or it may be taken in at the head but wasted back to the river through lower wasteways. When the Pleasant Valley and Lake Canal has an excess of 10 to 20 second-feet which it will not need for 24 hours it is usually cut back to the river at the Bingham Hill waste, though it might be carried on through the canal and tailed into Fossil Creek to reach the river again through the outlet of Fossil Creek Reservoir. The return water of the stream is of great importance in stretching the period during which the later rights may draw. During the summer this return is sufficient to supply a considerable part of the demand below the Larimer and Weld Canal, which permits a corresponding amount to be drawn from the river by later rights above. This return is of especial benefit to the Ogilvy Ditch, which is the lowest on the river. Its right is junior to practically every other right on the river, but the return water to the stream affords it a sufficient supply for the greater part of the season in average years.

The year 1916 was nearly normal and the dates on which the various rights failed that year may be assumed to be close to the average. Ordinarily it would be expected that on a small stream like the Cache la Poudre the flow of the stream at the head of the irrigated area would bear some close relation to the aggregate of the rights prior to the right cut-off, but this does not hold true. The return of seepage, water wasted back from canals, foreign water carried, exchange water turned into the river, low demand, and excessive decrees all upset any calculation along this line. The appropriation of the Larimer County Canal, priority No. 100, was cut on June 29 when the river at the canyon station was carrying approximately 1,480 second-feet. The rights senior to the right of the Larimer County Canal aggregate 3,600 second-feet.

On July 6 the appropriation of the Larimer County Canal No. 2, priority No. 57, was cut when the river was carrying approximately 1,000 second-feet. Rights prior to this appropriation aggregate 1,800 second feet. On August 1 the appropriation of the Lake Canal, priority No. 54, was cut when the river was carrying approximately 700 second-feet. Rights prior to this appropriation aggregate 1,600 second feet. On August 17 the Greeley Canal No. 2 was cut when the river was carrying 325 second-feet. The priority number of the first right is 37 and prior rights aggregate approximately 700 second-feet. On August 23 the Josh Ames Ditch, priority No. 25, was cut when the river was carrying 250 second-feet. Prior rights aggregate 500 second-feet.

From the preceding list of rights it will be noted that there have been many transfers of appropriations from one canal to another. Whether these transfers are of benefit or harmful to a community depends on whether the rights transferred are bona fide rights which have been properly used or whether they belong to the large class of excessive decrees given before conditions were well understood. Where a canal has a small excess of water which has developed from a better use of water or the waterlogging of land which has been irrigated, the transfer of this water does not damage any other right, yet extends the area irrigated and tends to increase the general prosperity of the community. On the other hand, where an appropriation has never been used except for the sole purpose of establishing a so-called right to it, its transfer is bound to affect adversely all rights subsequent to it, and, therefore, to be distinctly harmful to the community as a whole. To illustrate: The Boyd and Freeman Ditch has decrees for appropriations aggregating 99 second-feet, but its capacity is only 25 second-feet. It irrigates 650 acres and, considering the character of the soil, it is evident that 25 second-feet is much more than sufficient to supply all the water needed. In fact, at least 60 second-feet of its first appropriation, priority No. 6, could be sold without impairing in the least the chance of the ditch for full satisfaction throughout the season. If it were possible, and this 60 second-feet right were transferred to the Poudre Valley Canal, for instance, every right subsequent to priority No. 6 would be adversely affected. As the Boyd and Freeman Ditch has never, in fact, used the water, a transfer would be equivalent to taking the water away from subsequent appropriators whose rights would, thereupon, fail a week to three weeks earlier than they do at present.

Some idea of the money value of water rights in the river is given by the cost of water transferred, though it must be understood that these transfers were made some years ago. Parts of priorities No. 2, 19, and 29 were acquired by the North Poudre Irrigation Co. at the

rate of \$3,000 a second-foot, and a part of priority No. 17 was acquired by the same company for \$2,500 a second-foot. But parts of priorities No. 52 and 66, which were transferred to the North Poudre Canal, cost only \$150 a second-foot. Just recently the right of the Mason and Hottel mill race was abandoned to the river on payment of \$2,000 per second-foot by the interested canals.

The holding of direct irrigation water in small farm reservoirs is an accepted, well-established custom, due to the recognized economy of time and water the practice promotes. The extension of this custom to regulator reservoirs for the benefit of the whole stream would have a most beneficial effect, but any extension to large reservoirs of individual companies raises the question of where the line should be drawn. In permitting the transfer of 26 second-feet of priorities No. 52 and No. 66 to the North Poudre Canal the court decreed:

That petitioner (the North Poudre Irrigation Company) may, in times of scarcity of water, and for the purpose of making a more economical use of said water, and at times when other water is not being run in its ditch in sufficient quantity, use Halligan Dam and Reservoir, located on the North Fork of the Cache la Poudre, a short distance above headgate of petitioner's ditch, for the purpose of temporarily catching up said water and obtaining a sufficient head, thence to turn the same into the headgate of the said North Fork ditch without injuriously affecting the vested rights of said respondents or other water users in district No. 3.

In the adjudication of 1882, Warren Lake, which was then hardly more than a fishpond, was given a decree permitting it to draw approximately 15 second-feet of the appropriation of the Larimer County Canal No. 2, but there was no general adjudication of reservoir rights until a decree was handed down by the district court in 1909. By this decree 43 reservoirs were given 57 appropriations on first constructions and enlargements aggregating about 6,000,000,000 cubic feet, or 150,000 acre-feet. Because of inaccurate surveys or lack of surveys, there are many inconsistencies in these decrees, and very few of the decreed appropriations agree with the actual capacity of the reservoir as shown by later careful surveys or by measuring the inflow or outflow. Only a few transfers of reservoir rights have been made. When the North Poudre Irrigation Co. disposed of its interest in Douglass Reservoir the appropriation was retained and transferred to Reservoirs No. 5 and No. 6 to permit these reservoirs to fill from the main river through the Poudre Valley Canal. The appropriation of No. 6 in the North Fork was then transferred to Halligan and No. 15 Reservoirs.

DISTRIBUTION FROM RIVER.

The Cache la Poudre basin is water district No. 3, and to the water commissioner of the district is delegated the duty of turning the water in the stream to the various canals in accordance with the quality,

quantity, and priority of their appropriations. The distribution of the normal flow alone would be a difficult problem, in view of the great daily fluctuation, but the problem is further complicated by the exchanges made, the foreign water and reservoir water carried in the natural channels of the basin, and the seepage return to the stream.

The present incumbent ^a has been water commissioner of the district for more than 25 years; and his long experience, good judgment, fearlessness, and unquestioned honesty insure a just distribution of the water in the stream. He receives each day by telephone reports of all activities within the district, including the flow of the river at various points, changes in demands of the various canals, exchanges desired, and foreign and reservoir water turned into the river for carriage or exchange. With this information before him and his knowledge of the amount of seepage return he is able to determine the amount each canal may properly divert. If the flow in any canal must be increased or decreased he telephones early in the morning to the headgate man of the canal and gives him a new gage height at which the canal must be run until further notice.

With the object of keeping the gain or loss properly placed as the river rises or falls, the order is sometimes reversed and the headgate man is instructed to hold the river below his canal at a certain stage and to divert the remainder of the flow. For instance, when the river reaches the stage at which the appropriation of the Larimer County Canal for 463 second-feet is entitled to draw, the commissioner will direct the headgate man of the canal to pass enough water to keep the river up to a gage of 3.7 at Shipp's bridge just below and to take the remainder into the canal. By holding the Shipp's bridge gage at that point enough water is sent down to supply all prior rights below, and the rise and fall of the canal coincides with the varying supply in the river to which the canal is entitled by that appropriation.

TABLE 6.—*Diversions, in acre-feet, from the Cache la Poudre River in 1916.*

	For storage.												Total.
	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	
North Poudre Canal.	0	0	3,472	1,712	0	0	0	0	0	1,620	1,080	310	8,194
Poudre Valley Canal ^a	0	0	0	0	0	2,230	1,400	0	0	0	0	0	3,630
Pleasant Valley and Lake Canal.....	0	0	0	437	0	0	0	0	0	0	0	0	437
Larimer County Canal ^b	0	0	0	370	1,875	2,421	1,990	0	2,746	2,812	0	0	12,214
Jackson Ditch ^c	0	0	0	0	0	0	0	0	0	0	0	0	0

^a Storage of foreign water and Windsor Reservoir exchange. Direct flow chiefly foreign water to lands under North Poudre Canal.

^b Storage practically all foreign water.

^c Larimer County water held temporarily in Long Pond and then exchanged for river water.

TABLE 6.—*Diversions, in acre-feet, from the Cache la Poudre River in 1916—Con.*

	For storage.												Total.
	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	
Little Cache la Poudre Ditch ¹	0	522	180	50	300	0	1,176	0	41	898	1,972	420	5,559
Taylor and Gill Ditch.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Larimer County Canal No. 2.....	0	0	0	1,057	533	200	0	0	0	0	0	0	1,790
New Mercer Canal.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Arthur Ditch.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Larimer and Weld Canal.....	1,410	1,236	0	630	900	0	0	0	935	902	718	690	7,421
Josh Ames Ditch.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Lake Canal.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Coy Ditch.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Cache la Poudre Reservoir feeder.....	0	0	0	980	0	0	0	0	0	2,610	3,240	2,420	9,250
Chaffee Ditch.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Boxelder Ditch.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Fossil Creek Reservoir feeder.....	0	1,492	1,602	0	0	0	0	0	0	0	0	0	3,094
Greeley Canal No. 2.....	0	0	0	0	0	0	0	0	420	500	0	0	920
Whitney Ditch.....	0	0	0	0	0	0	0	0	0	0	0	0	0
B. H. Eaton Ditch.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Jones Ditch.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Greeley Canal No. 3.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Boyd and Freeman Ditch.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Ogilvy Ditch.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Total.....	1,410	3,250	5,254	5,236	3,608	4,851	4,566	0	4,142	9,342	7,010	3,840	52,509

	For direct irrigation.								Grand total.
	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Total.	
North Poudre Canal.....	1,223	7,097	8,592	8,365	3,236	1,396	0	29,909	38,103
Poudre Valley Canal ¹	0	697	1,540	1,946	1,398	0	0	5,581	9,211
Pleasant Valley and Lake Canal.....	1,357	3,253	4,341	3,543	3,080	1,902	0	17,476	17,913
Larimer County Canal ²	0	6,887	22,671	17,680	10,691	3,729	0	61,658	73,872
Jackson Ditch ³	77	1,219	2,349	1,598	1,059	548	0	6,850	6,850
Little Cache la Poudre Ditch ⁴	0	959	1,472	2,008	1,751	21	0	6,211	11,770
Taylor and Gill Ditch.....	365	466	794	786	740	590	276	4,017	4,017
Larimer County Canal No. 2.....	154	3,562	4,455	2,327	755	68	0	11,321	13,111
New Mercer Canal.....	31	2,016	2,147	2,059	1,387	414	0	8,054	8,054
Arthur Ditch.....	491	1,663	1,264	1,703	737	200	79	6,137	6,137
Larimer and Weld Canal.....	1,237	13,344	33,334	6,908	3,715	2,993	0	61,531	68,952
Josh Ames Ditch.....	28	43	451	576	368	17	0	1,483	1,483
Lake Canal.....	0	4,035	5,116	1,992	304	0	0	11,447	11,447
Coy Ditch.....	0	105	114	366	164	0	0	749	749
Cache la Poudre Reservoir feeder.....	0	0	0	0	0	0	0	0	9,250
Chaffee Ditch.....	0	277	64	351	255	0	0	947	947
Boxelder Ditch.....	0	514	1,042	948	371	40	0	2,915	2,915
Fossil Creek Reservoir feeder.....	0	0	0	0	0	0	0	0	3,094
Greeley Canal No. 2.....	1,681	16,431	19,174	4,690	4,045	2,342	0	48,363	49,283
Whitney Ditch.....	109	451	1,086	1,743	1,587	984	64	6,024	6,024
B. H. Eaton Ditch.....	169	277	579	1,115	411	278	0	2,829	2,829
Jones Ditch.....	0	23	312	455	656	94	0	1,540	1,540
Greeley Canal No. 3.....	1,691	2,973	3,958	4,812	3,714	3,624	438	21,210	21,210
Boyd and Freeman Ditch.....	0	0	408	421	382	168	0	1,379	1,379
Ogilvy Ditch.....	607	2,554	1,618	2,071	2,266	1,372	0	10,488	10,488
Total.....	9,220	68,846	116,881	68,463	43,072	20,780	857	328,119	380,628

¹ Storage of foreign water and Windsor Reservoir exchange. Direct flow chiefly foreign water to lands under North Poudre Canal.

² Storage practically all foreign water.

³ Larimer County water held temporarily in Long Pond and then exchanged for river water.

⁴ July storage chiefly Windsor Reservoir exchange.

TABLE 7.—*Diversions, in acre-feet, from the Cache la Poudre River in 1917.*

	For storage.												Total.
	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	
North Poudre Canal.....	0	0	495	3,402	6,400	530	0	0	0	10	0	0	10,827
Poudre Valley Canal.....	0	0	0	1,476	13,127	2,050	0	0	0	0	0	0	16,653
Pleasant Valley and Lake Canal.....	0	0	0	460	56	0	0	0	0	120	412	0	1,048
Larimer County Canal.....	0	0	0	5,137	4,415	514	954	0	4,920	554	0	0	16,494
Jackson Ditch.....	0	0	0	0	131	383	0	0	0	0	0	0	514
Little Cache la Poudre Ditch.....	0	0	294	668	2,850	125	316	0	58	2,300	1,704	486	8,801
Taylor and Gill Ditch.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Larimer County Canal No. 2.....	0	0	0	0	1,732	129	73	0	0	0	0	0	1,934
New Mercer Canal.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Arthur Ditch.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Larimer and Weld Canal.....	406	1,260	2,212	700	7,220	0	0	0	0	0	1,400	0	13,198
Josh Ames Ditch.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Lake Canal.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Coy Ditch.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Cache la Poudre Reservoir feeder.....	0	0	686	1,260	0	0	0	0	0	2,140	2,212	1,720	8,018
Chaffee Ditch.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Boxelder Ditch.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Fossil Creek Reservoir feeder.....	2,568	2,164	1,358	0	0	0	0	0	0	0	588	0	6,678
Greeley Canal No. 2.....	0	0	0	0	0	0	0	0	360	250	0	0	640
Whitney Ditch.....	0	0	0	0	0	0	0	0	0	0	0	0	0
B. H. Eaton Ditch.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Jones Ditch.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Greeley Canal No. 3.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Boyd and Freeman Ditch.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Ogilvy Ditch.....	0	0	0	0	0	0	0	0	0	0	0	0	0
Total.....	2,974	3,424	5,045	13,103	35,931	3,731	1,343	0	5,338	5,394	6,311	2,203	84,805

141 acre-feet from Halligan carried for storage in Stuchel Lake for Wellington water supply.

	For direct irrigation.								Grand total.
	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Total.	
North Poudre Canal.....	0	118	8,198	12,369	10,895	2,149	0	33,729	44,556
Poudre Valley Canal.....	0	0	662	2,475	358	51	0	3,546	20,199
Pleasant Valley and Lake Canal.....	453	202	4,945	6,171	3,495	1,945	0	17,211	18,259
Larimer County Canal.....	0	8,087	22,626	27,897	10,557	1,813	0	70,980	87,474
Jackson Ditch.....	0	86	1,261	2,391	1,254	666	15	5,673	6,187
Little Cache la Poudre Ditch.....	0	0	1,855	1,977	1,543	204	0	5,579	14,380
Taylor and Gill Ditch.....	264	231	560	810	784	560	0	3,209	3,209
Larimer County Canal No. 2.....	0	0	4,096	6,795	396	121	0	11,408	13,342
New Mercer Canal.....	0	47	3,075	3,592	1,214	243	0	8,171	8,171
Arthur Ditch.....	0	281	1,495	2,241	453	73	0	4,543	4,543
Larimer and Weld Canal.....	587	2,013	30,910	25,923	3,322	4,480	0	67,235	80,433
Josh Ames Ditch.....	0	0	178	698	532	0	0	1,408	1,408
Lake Canal.....	0	213	5,454	6,156	158	0	0	11,981	11,981
Coy Ditch.....	0	0	0	204	363	41	0	608	608
Cache la Poudre Reservoir feeder.....	0	0	0	0	0	0	0	0	8,018
Chaffee Ditch.....	0	0	286	514	198	0	0	998	998
Boxelder Ditch.....	0	0	1,272	1,255	1,645	991	0	5,163	5,163
Fossil Creek Reservoir feeder.....	0	0	0	0	0	0	0	0	6,678
Greeley Canal No. 2.....	0	2,164	18,349	25,064	3,442	1,581	0	50,600	51,240
Whitney Ditch.....	0	0	843	1,478	1,635	997	0	4,953	4,953
B. H. Eaton Ditch.....	0	329	1,071	1,261	989	477	21	4,148	4,148
Jones Ditch.....	0	0	85	29	381	457	0	952	952
Greeley Canal No. 3.....	275	943	2,899	4,544	4,191	3,046	0	15,901	15,901
Boyd and Freeman Ditch.....	0	96	134	354	538	254	0	1,376	1,376
Ogilvy Ditch.....	0	686	2,145	2,892	3,161	1,881	11	10,776	10,776
Total.....	1,579	15,499	112,399	137,090	51,540	22,030	47	340,148	424,953

Almost without exception the distribution is made in strict accordance with appropriations and priorities. Little attention is paid to the small ditches above the mouth of the canyon or at the head of tributaries entering below the canyon. The general feeling is that irrigation from these small ditches does not affect to any great extent the total supply of water available below, except possibly in very dry years, and that the trouble and expense of keeping track of them would more than counterbalance any good which might result. Below the canyon on the main stream a few small ditches divert practically at will on early excessive decrees, but the greater part of this water is wasted directly back to the river and the total supply is diminished by only a small amount. Another exception is the practice of allowing some canals to "accumulate" water for a few days. For instance, the appropriation of 175 second-feet of the Larimer County Canal No. 2 usually fails about July 10, and instead of allowing the canal to draw a varying and dwindling head for perhaps 10 days, it is permitted to draw a good head for 3 or 4 days and is then cut off entirely. By general consent certain exceptions which work out to the best advantage are made in the case of reservoirs. The Cache la Poudre and the Fossil Creek Reservoirs have first call on the water which heretofore passed through the Mason and Hottel mill race and they may be filled slowly with the assurance that they can be topped out when the spring flood comes down. The filling of Claymore Lake may also be delayed with the assurance that it can be completely filled in a week during the flood period. So during a part of the storage season water which might be demanded by these reservoirs may be diverted to others which have less chance of filling either on account of late priorities or small intakes.

DIVERSIONS FROM THE RIVER IN 1916 AND 1917.

Diversions from the river for the 2 years of the investigation are shown in Tables 7 and 8 and figure 3. The ratio of diversions for storage to the total diversion was 14 per cent in 1916 and 20 per cent in 1917, but in neither year was the total available storage capacity used. These figures do not include storage in the mountain reservoirs of the basin, but were these included the figures would not be changed greatly.

Diversions for direct irrigation begin in April and continue until the first part of October, though the greater part of the demand is from April 15 to September 15. Water for storage is drawn throughout the year except in August, but practically all the water stored between June 15 and the end of the season is foreign water or "Wind-sor exchange." The large amount of storage in April and May, 1917, is accounted for by a high river and heavy rains which decreased the demand for water for direct irrigation.

DUTY OF THE RIVER.

The average available supply of water in the Cache la Poudre amounts to 375,000 acre-feet, which includes the normal flow of the river and its tributaries and 35,000 acre-feet of foreign water, but does not include the seepage return to the river. Applied to the 225,000 acres irrigated in the valley it gives for the stream, as a whole, a duty of 1.67 acre-feet per acre; or, expressed differently, each second-foot of the average annual discharge irrigates 434 acres. This high general duty is made possible only by the large percentage of the flow held in storage for use at critical times and by the large amount of return seepage which is used several times over again.

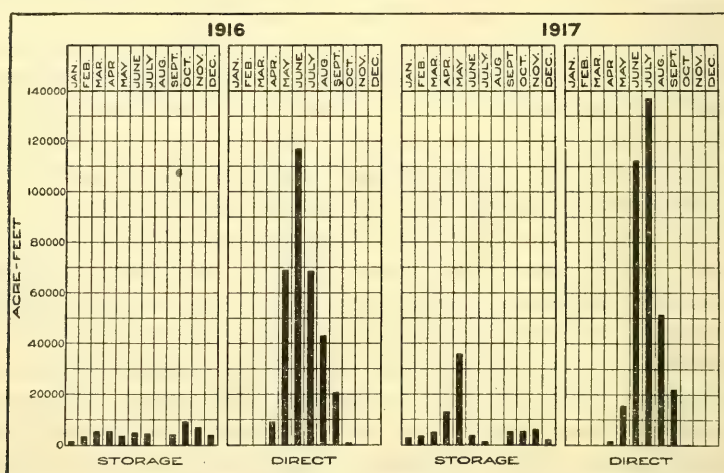


FIG. 3.—Diversions from the Cache la Poudre River for storage and for direct irrigation compared for the 2 years of the investigation.

THE CONSUMPTIVE DUTY.

The water actually consumed, or the consumptive duty, may be arrived at by considering in addition the water which passes into the South Platte River from the Cache la Poudre River, Lone Tree Creek, and various canal wasteways dumping into the South Platte or Crow Creek. In 1916 the available supply exclusive of seepage return was 336,000 acre-feet, and 79,000 acre-feet passed out of the valley. The net consumption of 257,000 acre-feet on the 218,000 acres irrigated that year gives a duty of 1.18 acre-feet per acre. In 1917 the supply was 608,000 acre-feet, and 309,000⁷ acre-feet passed into the South Platte. The net consumption of 299,000 acre-feet on the 225,000 acres irrigated that year gives a duty of 1.33 acre-feet per acre. As the water supply during 1916 was slightly below normal

⁷ Partly estimated.

and in 1917 was far above normal, it seems reasonable to assume that the average consumptive duty is approximately 1.25 acre-feet per acre.⁸

NONPRODUCTIVE AND WASTE LAND.

With the object of determining how the farm land of the valley is utilized and the proportion of nonproductive and waste land, careful surveys were made of $7\frac{1}{2}$ sections of land at different points in the valley. A summary of the data obtained by these surveys is contained in Table 8.

TABLE 8.—*Utilization of farm land in the Cache la Poudre Valley.*

	3 sections near Greeley (per cent).			3 sections northeast of Fort Collins (per cent).			$1\frac{1}{2}$ sections northeast of Fort Collins (per cent).		
	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
Cultivated.....	89.2	92.8	84.5	81.4	90.7	57.2	71.0	.....	.....
Irrigated but not cultivated.....	.4	2.4	.0	4.4	19.7	.0	8.0	.....	.....
Public roads.....	2.3	2.4	1.9	2.1	2.4	1.1	1.6	.....	.....
Private roads.....	.5	1.0	.0	.3	1.0	.0	1.1	.....	.....
Railroad right of way.....	.9	2.6	.0	.0	.0	.0	.0	.....	.....
Farmstead.....	2.1	3.1	1.4	2.0	3.7	.8	4.9	.....	.....
Wood lots.....	.0	.0	.0	.4	1.9	.0	.0	.....	.....
Canals.....	.3	1.6	.0	.7	3.6	.0	2.0	.....	.....
Field laterals.....	3.0	4.9	2.0	2.9	5.4	1.1	2.0	.....	.....
High land.....	.0	.0	.0	1.6	16.8	.0	.0	.....	.....
Seepage land.....	.0	.0	.0	2.7	14.1	.0	.7	.....	.....
Marginal waste.....	1.3	2.5	.3	1.5	4.6	.6	8.7	.....	.....

The 3 sections near Greeley include some of the most highly developed land of the valley, with prices ranging from \$300 to \$400 per acre. It is smooth, gently sloping land, easy to cultivate and irrigate. The water rights supplying it are excellent, and wet spots which developed after years of irrigation have been drained. On this land the nonproductive area is at a minimum. The 3 sections near Fort Collins are less valuable, ranging in price from \$150 to \$200 per acre. The land is more rolling and includes some high spots or knolls not reached by the ditches and some wet spots which have not yet been drained. The section and a half northwest of Fort Collins has been farmed by tenants for some years and shows the result of neglect. A low percentage of the land is cultivated and the marginal waste is particularly high. The high percentage of land included under the head of farmstead was in this case due to a number of pens for sheep feeding.

The best farm practice requires that the percentage of land devoted to nonproductive use be reduced to a minimum, and that there be no real waste of land. Public roads will require 2.3 per cent of the area of farms in a section. Private roads should not require more than 0.5 per cent. At present the roads are 12 feet wide and

⁸ This calculation does not take into account return seepage from Poudre Valley land going directly into the South Platte. Taking this into account would reduce slightly the quantity of water actually consumed.

generally unimproved, but might profitably be widened and made permanent by grading and systematic maintenance work. Farmsteads should not be held to a minimum and considerations of comfort and health should govern their size. For field laterals not more than 2.5 to 3 per cent should be required, the percentage varying with the crop, the slope of the land, and other conditions. Marginal waste should not exceed 1 per cent. In general, not more than 2 feet is required at the side of a field and at the end not more than 6 to 8 feet.

CANAL SYSTEMS.

In the section of the Cache la Poudre Valley under investigation there are about 25 irrigation canals diverting from the river. Two or three of these irrigate only a few acres each, but 23 were considered of sufficient importance to be included in the investigation. Beginning at the head of the stream and listing them in the order in which they head these canals are: North Poudre Canal or North Fork Ditch; Poudre Valley Canal; Pleasant Valley and Lake Canal or Highline; Larimer County Canal; Water Supply & Storage Co. Canal or Ditch; Jackson Ditch or Dry Creek Ditch; Little Cache la Poudre Ditch; Taylor and Gill Ditch; Larimer County Canal No. 2; New Mercer Canal; Arthur Ditch, Tom Ditch, or Fort Collins Canal; Larimer and Weld Canal or Eaton Ditch; Josh Ames Ditch; Lake Canal; Coy Ditch; Chaffee Ditch; Boxelder Ditch; Greeley Canal No. 2, or Union Colony Canal No. 2, or Cache la Poudre Canal; Whitney Ditch; B. H. Eaton Ditch; Jones Ditch; Greeley Canal No. 3, or Union Colony Canal No. 3; Boyd and Freeman Ditch; and Ogilvy Ditch. The areas irrigated by the more important of these canals in 1916 are shown in Plates X to XIII.

Excepting many small ditches which are owned by individuals, the canals of the valley are organized in some cooperative form. There are two irrigation districts and a number of informal partnerships, but the great majority are joint-stock companies.

The development of irrigation in the valley was so rapid that nearly all the canal systems had been successfully completed before financing by irrigation districts became necessary. For this reason there are only two districts in the valley, the Park Creek and the Greeley-Poudre. The Park Creek district includes a few sections under the North Poudre Canal and receives its water from that canal and from rights in Fish Creek. The Greeley-Poudre district covers a large area between Greeley and Carr, but financial and legal difficulties several years ago caused a suspension of activities after only a part of its construction program had been carried out.

The partnerships are rarely formally organized, but operate in accordance with customs which have to a certain extent been crystallized in the laws of the State. Often each partner does an amount

of cleaning and other maintenance work in proportion to his interest in the ditch, though he is required by law to do only his share from the headgate to the point at which his lateral diverts. For the distribution of water in the ditch, division boxes or weirs are used very generally and a continuous flow is delivered until the supply falls short or the demand decreases. A short supply is usually rotated among the partners, each receiving an even amount of water for a time proportionate to his interest. Many laterals of canals are handled in this manner.

Many of the cooperative companies were originally organized as such, the capital stock being placed at the cost of construction of the canal and sold for cash or issued to the builders in proportion to the work done by each. Others were controlled originally by corporations organized to build canals and to derive profits from the sale of water rights, but, in accordance with terms commonly contained in the water right contracts, cooperative companies were organized by the owners of water rights to take over the systems after a certain number of rights had been sold. In such cases shares were issued in proportion to the water rights held. In general, a share of stock of a cooperative company represents a proportionate part of the water supply of the ditch at any time and this water may be used on any land served by the system, subject, of course, to due notice of a desire to change the point of delivery. Holdings of stock are not restricted in any manner and vary with the water requirements or finances of the individual. This, together with variations in supply and demand due to wet and dry seasons and crop changes in rotation systems, has given rise to the common practice of renting shares or water for a season or less.

The organization of the cooperative companies shows no unusual features. The stockholders elect a board of directors who in turn elect officers to conduct the business of the company. These include always a president, secretary, treasurer, and superintendent. Riders, headgate men, and gangs for repair and maintenance work are employed by either the superintendent, president, or the directors. Engineers, hydrographers, and office help are employed only for special work or for short periods.

The ordinary expenses of the cooperative companies are met by levying annual assessments on the capital stock. These assessments vary from a few cents to a dollar or two an acre, but the average is close to 25 cents. Several canals of the valley in their capacity as common carriers of reservoir water make their charges for this service high enough to defray most of their expenses. In the case of the Greeley Canal No. 2 the income from carrying reservoir water is sufficient to meet all ordinary expenses and assessments are levied only on special occasions. However, the money comes out of the

farmer's pocket whether it is in the form of an assessment or a carriage charge.

The canal structures of the valley show various designs and types of construction, but in general permanent structures of reinforced concrete are replacing the old timber structures. Diversion dams are rock and brush, timber, or concrete. Rock and brush dams are used by only a few of the small ditches on the lower reaches of the river. The majority of the dams are simple structures consisting of piles of rock cribs topped by heavy timber decks on which there are permanent crests or standards for flashboards. Wings may be of masonry, concrete, or timber and seepage underneath is usually cut off by a row of sheet piling. A dam of this type is shown in Plate II, figure 1. The majority of the newer dams are of reinforced concrete set on piles or rock crib, and having well-designed overflow lips and suitable sluices to scour the channels past the canal intakes. A dam of this type is shown in Plate I, figure 1. The crest of the Larimer County Dam (Pl. I, fig. 1) was found to be too low for certain stages of the river and was raised 12 inches with 3 by 12 planks fastened to iron pins sunk in the crest. In Plate I, figure 2, is shown another type of concrete dam in which the water is held up by flashboards.

The drift guard at the head of the Larimer and Weld Canal, shown in Plate II, figure 2, is of the same general design as others in the valley. The structure itself and the individual timbers of the grating are placed at such an angle that the drift tends to slide downstream instead of lodging. A few canals depend on booms of logs chained end to end and anchored so that they swing out in front of the gates.

Headgates are made of timber, concrete, or stone and are fitted with wooden or iron gates raised by some combination of screw and lever, or rack and pinion. A type of gate and lifting device is shown in Plate III, figure 1. Wasteways and sand sluices are of similar design. Some of the canals use an adaptation of the Land sand gate with diagonal ducts to cut out the greater part of the sand near the bottom of the canal.

In the construction of the canals of the valley flumes are avoided even at great expense as is evidenced by the construction shown in Plate III, figure 2. Some of those which were built are being eliminated by the construction of tunnels or inverted syphons, the longest in the valley, a half-mile flume along the side of the canon at the head of the North Poudre Canal, being replaced by a tunnel 1,600 feet in length through solid rock. There still remain a number of timber or concrete flumes for crossings of less than 200 feet, and one of these is shown in Plate IV, figure 1. Rating flumes at the head of canals are usually of concrete or timber, though a few of masonry



FIG. 1.—DIVERSION DAM OF THE LARIMER COUNTY CANAL.



FIG. 2.—DIVERSION DAM OF THE B. H. EATON DITCH.



FIG. 1.—DIVERSION DAM OF THE GREELEY CANAL NO. 2.



FIG. 2.—DRIFT GUARD AT HEAD OF LARIMER AND WELD CANAL.



FIG. 1.—HEADGATE OF THE GREELEY CANAL NO. 2.



FIG. 2.—LINE OF THE Poudre VALLEY CANAL ROUNDING A ROCK BLUFF.



FIG. 1.—FLUME CARRYING TAIL OF LITTLE CACHE LA POUDE DITCH OVER DRY CREEK.

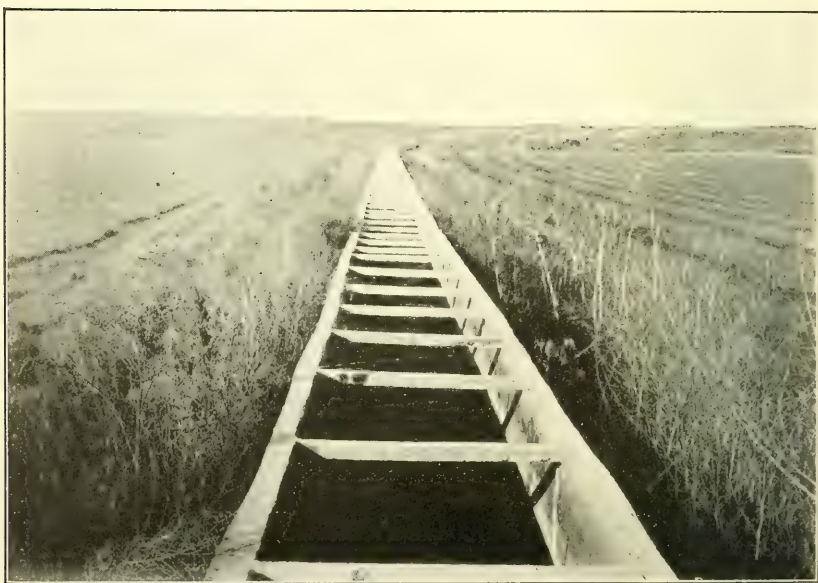


FIG. 2.—FLUME OR CHUTE CARRYING LONG POND WATER TO THE LARIMER AND WELD CANAL AND LINDENMEIER LAKE.

are found. Almost without exception they are designed or installed so that accurate measurements in them are almost impossible. In Plate IV, figure 2, is shown a flume or chute carrying water from Long Pond to the Larimer and Weld Canal and Lindenmeier Lake.

In the original construction of the canals of the valley contours were followed closely and only a few drops were necessary. These are generally of fair design and well constructed. A drop on the North Poudre system is shown in Plate V, figure 1, and in Plate V, figure 2, is shown a drop at the tail of a south-side ditch. Some of the canals with slightly excessive grades have been corrected by the construction of timber or concrete checks, in which part of the control is by flashboards. A typical check is shown in Plate VI, figure 1.

Laterals receive their supply from the main ditch through lines of tile ranging in diameter up to 24 inches. The upper end of the tile is set in a concrete bulkhead, and the flow through the pipe is controlled by an iron gate sliding in grooves in an iron framework which fits over the end of the tile. The gate stem is threaded, and the regulation is by one or two wheels working on these threads and against crosspieces. This gate is the Powell gate, so-called after its designer, B. F. Powell, of Rocky Ford.⁹

The most common device for measuring water to laterals is the rectangular weir which is found in sizes ranging from $1\frac{1}{2}$ to 10 feet in length of crest. The installation of these weirs is usually faulty, and the most accurate measurements can not be obtained with them. Bottom and end constructions are usually deficient, and entrance velocities are almost invariably too high. A combined weir and drop on a lateral of the Larimer County Canal is shown in Plate VI, figure 2. Division boxes are also very common for the distribution of water in small canals and laterals. Where an overfall is provided the division is fairly good, but otherwise it may or may not be. Typical division boxes are shown in Plate VII. The device used by the Pleasant Valley and Lake Canal for measuring water to users is shown in Plate VIII, figure 1. The crest of the weir is 4 inches above the bottom of the box, and the depth over the crest is measured on a plug about a foot back from the weir. The slots in the sides are intended for 2 by 12 inch planks, which are supposed to float in the slots and act as baffles.

With few exceptions, all lateral headgates and measuring devices are under the exclusive control of the canal company. Deliveries are made at the head of the lateral, and the canal company disclaims all responsibility for the distribution of water from the lateral and for the maintenance of the lateral. A continuous delivery of a prorata part of the flow is the method in common use on the majority of the

⁹ A drawing of this gate appears on page 39 of O. E. S. Bulletin No. 229.

canals, but when the supply becomes short some system of rotation between sections of the canal is instituted. The exception is the North Poudre Canal, which delivers on demand an allotment of water made at the beginning of the season. Under certain restrictions, reservoir water handled by ditches as carriers only is delivered on demand. Descriptions of some of the delivery systems of the canals of the valley are given in later sections of this report.

Maintenance problems in the valley present no new difficulties and on the whole give less trouble than might be expected. The Cache la Poudre is comparatively free from silt and sand, and deposits in canals are usually limited to short stretches at the head and at curves. These deposits are removed with scrapers in the spring or fall. Canal grades which were proper for the original canals were too heavy when these canals were enlarged, and at one time there was much erosion of banks and bottoms, but this condition has been corrected by the construction of checks or drops at proper points. For local erosion brush mattresses and rock riprapping are used, as shown in Plate VIII, figure 2. For river protection, rock riprap or rock-filled cribs, as shown in Plate IX, figure 1, are used. Breaks occur occasionally and are repaired in the ordinary manner with scrapers, care being taken to secure a good bond between the old and new material, to pack the new material carefully, and to raise the water on the new section as slowly as the necessity for water will warrant. The clear water and hot sunshine are favorable to the growth of moss, and by the first of July it begins to cause trouble on many of the canals. A moss-filled ditch is shown in Plate IX, figure 2. So far no successful method has been devised to prevent its growth or to remove it. Generally it is allowed to grow until it almost chokes the canal. The water is then cut out of the canal and the moss allowed to dry for two or three days. This helps to a certain extent, but is not a solution of the problem. Winter conditions have to be contended with by only two or three canals carrying water for storage in reservoirs. The winter supply rarely exceeds 100 second-feet, and little trouble is experienced in handling it.

LARIMER & WELD CANAL.

Early in 1879 the Larimer & Weld Irrigation Co. was incorporated with a capital stock of \$200,000 to take over the construction of the Larimer & Weld Canal, on which construction work had been begun in 1878, and to sell water rights. The water-right contracts provided that when rights to the capacity of the canal had been sold, 4 shares of the capital stock of the company were to be turned over to the holder of each right so that control of the company would pass to the owners of rights. After 366 rights had been disposed of the owners of rights felt that the capacity of the canal had been

reached and, upon applying to the courts, were upheld in their contention. At present the company is on a mutual basis with 1,423 shares of a par value of \$100 outstanding.

The water rights sold by the company called for the delivery of a continuous flow of 1.44 second-feet throughout the irrigation season when it was available from the river. At first one right was considered sufficient for 80 acres, but at present the average area served by a right, or 4 shares, is 160 acres. In 1880 rights, or the equivalent share, sold for \$400; in 1882, \$1,000; in 1887, \$1,200; and in 1917, \$4,500. Their present high value is due to the fact that there is still considerable land under the canal susceptible of irrigation, while the water supply is limited.

The expenses of the company are met by assessments levied on the capital stock and tolls collected for carrying reservoir water. In 1916 and 1917 the assessments were, respectively, \$5 and \$12.50 per share, the higher assessment being for the purpose of retiring some of the outstanding obligations of the company. For carrying water to fill Windsor Reservoir and others about \$1,350 was received each year. For carrying and distributing reservoir water about \$7,000 was received each year. Current expenses average about \$15,000 each year, or at the rate of approximately 35 cents per acre irrigated.

The canal heads just north of Fort Collins in section 34, township 8 north, range 69 west, and tails in Long Draw, a tributary of Crow Creek. Excluding the 16-mile extension beyond Owl Creek, the main canal is 40 miles long. The bottom width at the head is 30 feet and the slope of the sides is $1\frac{1}{2}$ to 1. The grade is 3 feet per mile for the first 3 miles, 2 feet per mile for the next 32 miles, and $1\frac{1}{2}$ feet per mile at the end. Its capacity is 750 second-feet. There are about 75 miles of main laterals operated by lateral companies and several hundred miles of small laterals and sublaterals.

In the tabulation shown on page 15 will be found a statement of the water rights of the canal. In acquiring the right to enlarge the old No. 10 ditch it was necessary for the company to give the original owners a free, unlimited, perpetual right to as much water as they could use on the lands they had previously irrigated, as long as the canal was drawing from the river. For this reason the first two appropriations are available for general use only when not required by the No. 10 rights.

The distribution from the canal of water received on direct appropriations presents no notable features. The company controls only the main canal and its responsibility ends with the delivery of the water to the laterals which are all owned and controlled by separate companies or individuals. The canal is in three sections, each of which is handled by a ditch rider. Diversions from the

canal are made through Powell gates which are kept locked so that they may be raised or lowered only by the ditch rider. The water delivered is measured over a rectangular weir, the depth over the weir being determined from tables carried by the rider, which show the depth to be carried over any crest length from 1 foot to 12 feet for any number of rights from $\frac{1}{4}$ to 68. In general, the water supply from the river is prorated among the users in accordance with the number of shares of stock which they hold, and to get the water to which he is entitled the user has only to notify the rider of the main ditch, or else the rider of the lateral from which he gets his supply, who will in turn notify the rider of the main canal. In times of very short supply a system of rotation of the supply between sections of the canal is instituted to avoid the wasteful practice of prorating a small supply. The company recognizes and encourages the practice of rotation of water among users, and the stockholders may have their water delivered to any lateral upon request. No records are kept of the delivery of water received on direct appropriations. Reservoir water and water received on direct appropriations are not run at the same time, and usually after the running of reservoir water is started the small amount received on appropriations from the river goes to make up losses in the canal or to pay for water advanced to the canal earlier in the season by the Windsor Reservoir.

Considerable care is used in the distribution of reservoir water, and complete records are kept by the secretary of the company. Before any water is delivered all carriage charges must be paid and credit entered on the books of the secretary. The delivery record of each user occupies one large sheet, 8 by 27 inches, of a loose-leaf book. Heading each sheet is the name of the owner, with a space in which may be entered the name of the tenant. At the left of the sheet there are blanks opposite the names of the various reservoirs in which may be entered the total number of rights of each with which the user is credited. Below are columns in which any debits or credits may be entered during the season. The right side of the sheet is devoted to records of delivery, with columns for every day from July 15 to September 15 and others in which are entered the name of the person ordering the water delivered and the lateral to which it was delivered. Under the dates are entered the numbers of "rights" delivered on that date. While this form of record is too large to be handled conveniently, the advantage of having the entire record on one sheet is obvious. Deliveries and credits may be compared at a glance for the benefit of users who inquire as to the standing of their accounts, and in addition there is little chance of any user exceeding his credit.

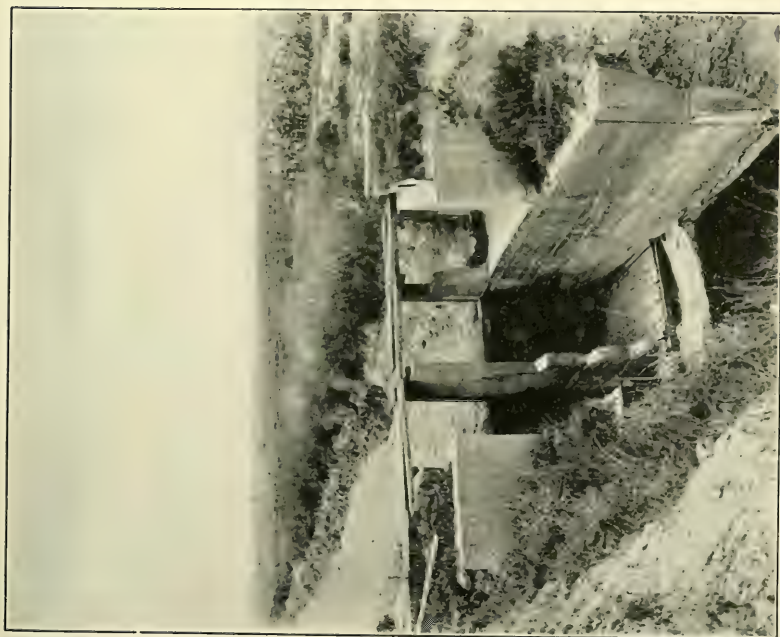


FIG. 1.—CONCRETE DROP ON THE INLET TO THE COAL CREEK RESERVOIR OF THE NORTH POUDRE IRRIGATION CO.

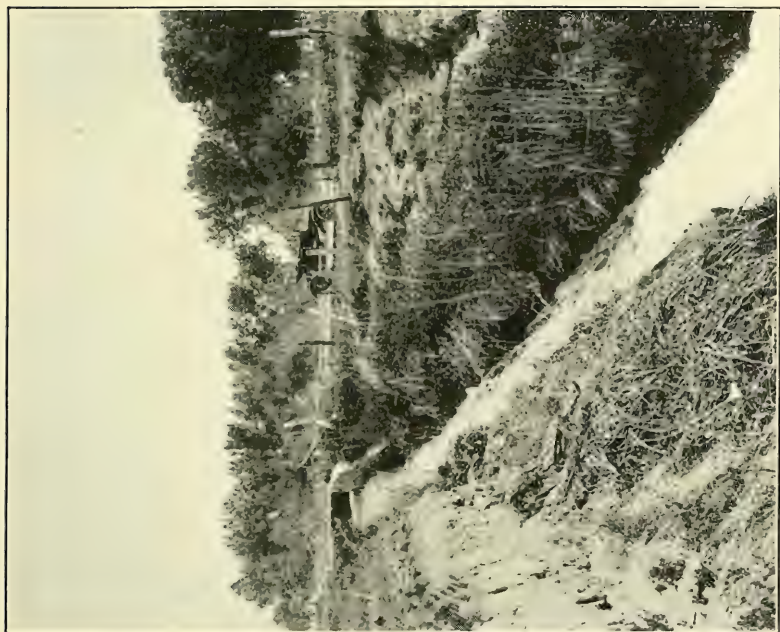


FIG. 2.—DROP AND CHUTE TO MAIL CREEK AT THE TAIL OF THE LARIMER COUNTY CANAL NO. 2.



FIG. 1.—CHECK IN THE LARIMER AND WELD CANAL.



FIG. 2.—WEIR AND DROP AT THE HEAD OF THE CULVER-BARTELS LATERAL OF THE LARIMER COUNTY CANAL.



FIG. 1.—COMMON TYPE OF DIVISION BOX IN WHICH THE DIVIDING BOARD IS MOVABLE AND IS HELD IN PLACE BY A CHAIN HOOKED OVER NAILS IN A CROSS PIECE.



FIG. 2.—DIVISION BOX ON THE ROBERTS LATERAL OF THE LARIMES AND WELD CANAL. THE DIVIDING BOARD IS CONTROLLED BY WHEELS WORKING ON THREADED RODS FASTENED TO THE BOARD.

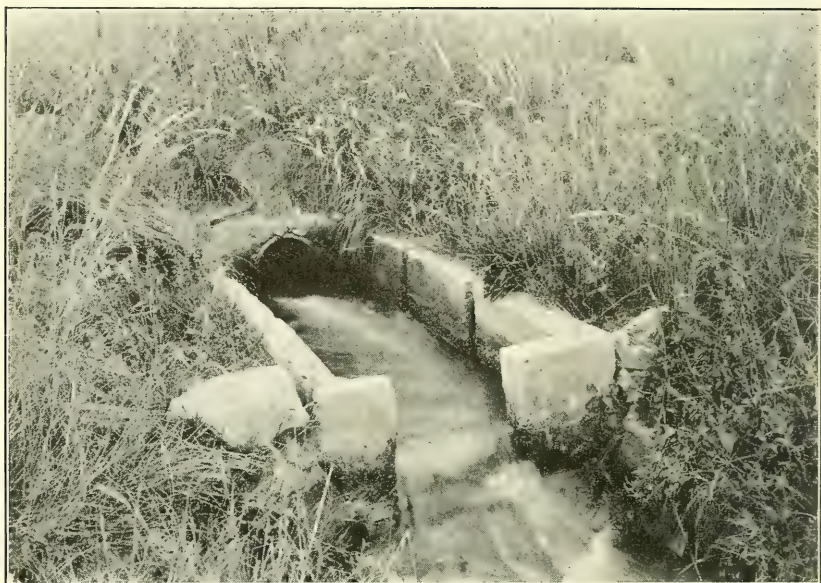


FIG. 1.—DEVICE FOR MEASURING WATER DELIVERED TO THE LATERALS OF THE PLEASANT VALLEY CANAL.

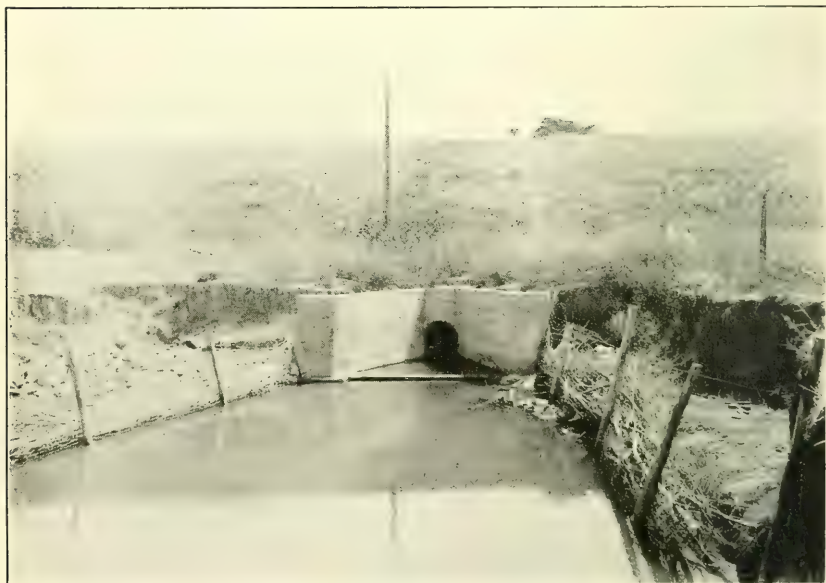


FIG. 2.—BRUSH MATTRESS BELOW OUTLET OF KLUVER LAKE TO STOP EROSION FROM BACKWASH.



FIG. 1.—ROCK-FILLED CRIBS USED AS RIVER PROTECTION AT THE HEAD OF THE ARTHUR DITCH.



FIG. 2.—MOSS IN THE OUTLET OF THE ROCKY RIDGE RESERVOIR.

The company rules provide that reservoir water will be carried when 250 rights are called for, but that the water will be cut off when the demand drops below 200 rights. Water is carried for \$10 per right and rights of other reservoirs must be made equal to those of Terry Lake or Windsor Reservoir, which range from a 16 to a 22 day run of $1\frac{1}{4}$ second-feet. Single day runs are carried at a minimum charge of \$1. On each right carried by the canal there is delivered to the lateral of the owner of the right 0.72 second-foot. To supply this 0.72 second-foot at the head of the lateral the company requires that there be delivered to the canal 1.25 second-feet, the difference taking care of losses in transit and inaccuracies and inequalities in distribution. Under a fairly constant demand and with better wire installations this margin of safety could no doubt be cut by 0.15 second-foot.

Demands for water are usually made by phone or in person to the secretary, who enters on a card provided for the purpose the name of the owner of the water, the name of the person ordering the water, the number of rights to be run, the lateral to which the water is to be delivered, and the period for which it is to be delivered. On account of the length of the canal, two days' notice is required for water to be delivered or cut off. Thus, to secure delivery Wednesday morning, water must be ordered before 1 o'clock Monday afternoon. At 1 o'clock each day the secretary begins the preparation of a list of the demands for the second day following, by revising the sheet of the preceding day. Orders which have expired are scratched off and new orders are entered, after which typewritten copies are made for the superintendent and the various ditch riders. The sheet is in the form shown below.

Sixteenth run, Saturday, Aug. 17, 1918.

Owner or renter.	Rights demanded.	Rights from Windsor.	Rights from Terry or other reservoirs as indicated in last column.	Lateral to which water is to be diverted.	Period to be run.
Anderson, J. P.	2	2		Owl Creek	15th to 19th.
Anderson, L. G.	$1\frac{1}{2}$	.....	$1\frac{1}{2}$	Lucas.	
Beard & Anderson.	2	1	1	Decker.	
Weber, Henry.	1	.....	1	Roullard.	

Résumé: Windsor, $181\frac{1}{2}$; Terry, 77; Worster, 10; Douglass, $17\frac{1}{2}$. Total demanded, 286 rights.

Upon receipt of this sheet the ditch riders prepare cards for each lateral, showing the amount of water ordered by each stockholder under the lateral. On the second morning following the water is

turned out to the various laterals as ordered and the cards are tacked on the lateral gates to serve as a guide for distribution by the riders of the laterals. The system of distribution from the laterals is practically the same as for the main canal, the water being measured over weirs except in a few cases where division boxes are used.

The copy of the order sheet sent to the superintendent reaches him the same afternoon, thus giving him 36 hours to increase or decrease the supply in the canal to meet the demand. To assist him with this part of the work the canal employs an expert hydrographer who measures all the water received by the canal for carriage and keeps a record which shows the number of cubic feet delivered direct by each reservoir or its account by exchange and the number of rights of that reservoir delivered by the canal. At the end of the season these quantities must balance, but the economical and satisfactory operation of the canal requires that there be much "swapping" of credits during the season, as in 1916, when Douglass Reservoir rights had been supplied for over a month before any Douglass water was received by the canal. In general, the supplies in Curtis, Kluver, and Douglass Reservoirs are drawn at a uniform rate, while the fluctuation in demand is taken care of by increasing or decreasing the outflow of the others, chiefly Terry Lake. On Sundays and at other times when there is a short demand, instead of cutting off at its source the reservoir water being received through Dry Creek, it is turned into Terry Lake and, under proper credit, held there for later use. On account of the long inlet canal and the difficulty of filling, the greater part of the surplus reservoir water, at the end of the season, is usually left in Windsor Reservoir No. 8. The lands irrigated are shown in Plate X.

LARIMER COUNTY CANAL.

The Larimer County Canal was initiated in 1880, when the Larimer County Ditch Co. was incorporated to build a canal and sell water rights under it. Arrangements were made with the owners of the Smith Ditch by which the Larimer County Ditch Co. acquired their right of way and in the spring of 1881 actual construction work on the canal was begun. From the start it was realized that the water supply directly from the river would be insufficient, and the construction of reservoirs to increase the supply was begun soon after. The company did not prosper, and in 1892 the system was taken over by the Water Supply & Storage Co., which had been organized by holders of rights in the ditch. This is a cooperative company with a capital stock of \$60,000 divided into 600 shares of a par value of \$100. The present value is close to \$6,000 per share.

Expenses of this company are met by assessments levied on the capital stock. These assessments average about \$100 per share, pro-

ducing a fund of \$60,000. Of this, \$20,000 is to cover interest charges on indebtedness and \$10,000 goes into a sinking fund. Ordinary operation and maintenance costs are covered by the remaining \$30,000, which is at the rate of approximately 65 cents per acre irrigated.

The Water Supply & Storage Co. system includes 11 reservoirs with an aggregate capacity of 26,000 acre-feet, 4 canals tapping other watersheds and diverting water into the Cache la Poudre, the Larimer County Canal, and an interest in the Jackson Ditch.

The Larimer County Canal is the distributing canal for the system and also supplies the lower reservoirs of the system. It heads in section 13, township 8 north, range 70 west, and extends eastward 75 miles to Owl Creek, into which it tails. The area irrigated is shown in Plate XI. The canal is 24 feet wide on the bottom, has a grade ranging from 1.32 to 3.16 feet per mile, and will carry 600 second-feet. There are about 50 laterals, with length of 150 miles.

At the head of the Cache la Poudre River the company owns four ditches which divert water from other sheds and turn it into the Cache la Poudre to be stored in Chambers Lake or diverted below into the Larimer County Canal. The Skyline Ditch intercepts water from tributaries of the Laramie River, the Cameron Pass Ditch diverts from the Michigan River shed, and two ditches divert the headwaters of the Grand River. For carrying this foreign water in the channel of the Cache la Poudre the water commissioner deducts 5 per cent for losses in transit.

The company owns an interest in the Jackson Ditch, acquired by purchase from the Larimer & Weld Reservoir Co., and a further interest was obtained by an exchange arrangement with individuals under the Jackson Ditch whose farms lie partly above the ditch. Contracts covering this exchange arrangement provide that the Water Supply & Storage Co. acquires a definite amount of stock of the Jackson Ditch, and the water secured on it is tailed into Long Pond. In exchange the individual acquires the right to an equal amount of water, less a small per cent for loss, from the Larimer County Canal throughout the season for his high land. The Water Supply & Storage Co. benefits by the arrangement because it receives the Jackson water throughout the season constantly, while the demand on the Larimer County Canal is intermittent.

Three of the reservoirs of the company, Chambers, Lost, and Laramie Lakes, with an aggregate capacity of approximately 7,000 acre-feet, are located at the head of the Cache la Poudre and in addition to storing water of the Cache la Poudre may be used to hold up foreign water brought over from other sheds.

Of the lower reservoirs Black Hollow, with a capacity of 5,760 acre-feet, is on the line of the canal about 25 miles from the tail of

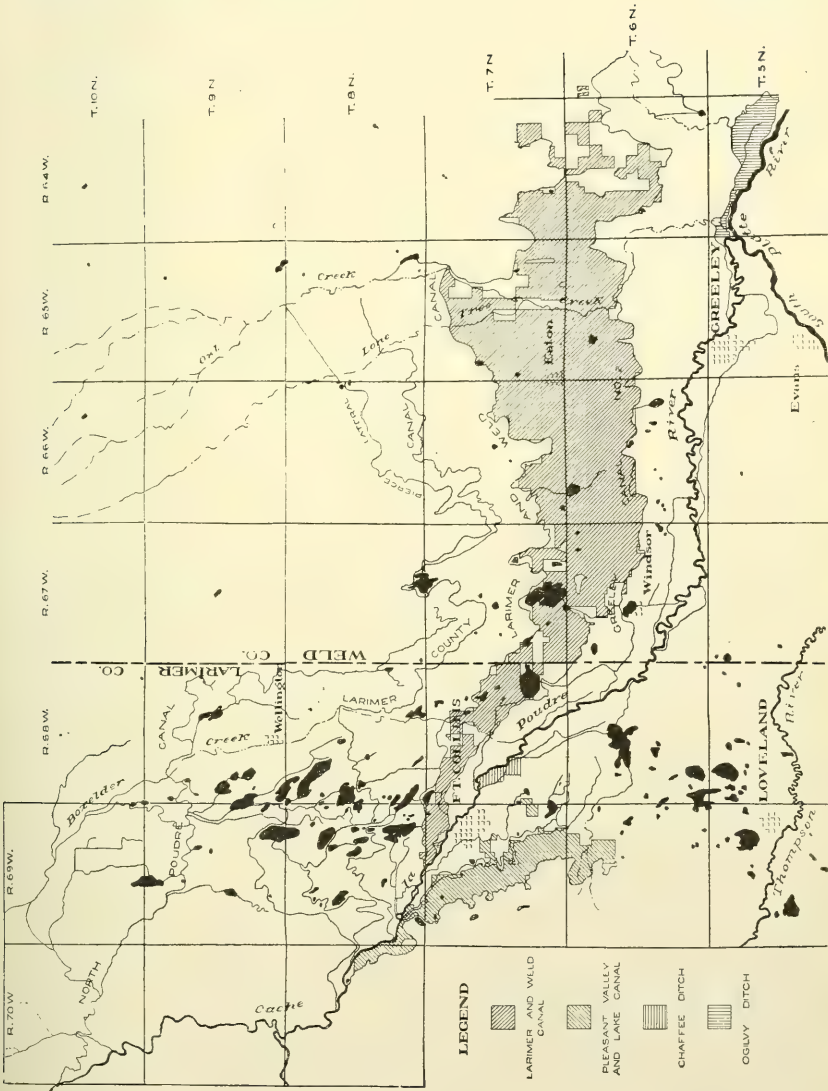
the ditch. Owing to its position this reservoir does away with the usual operation troubles at the lower end of long canals. The remaining reservoirs of the system are supplied by the Larimer County Canal, and the water stored in them may be used only by exchange. These reservoirs are listed below, with their capacities:

Reservoir :	Capacity in acre-feet.
Curtis Lake-----	780
Rocky Ridge Reservoir-----	4,730
Kluver Lake-----	815
Reservoir No. 4-----	987
Long Pond-----	4,017
Lindenmeier Lake-----	918
Richards Lake-----	1,056

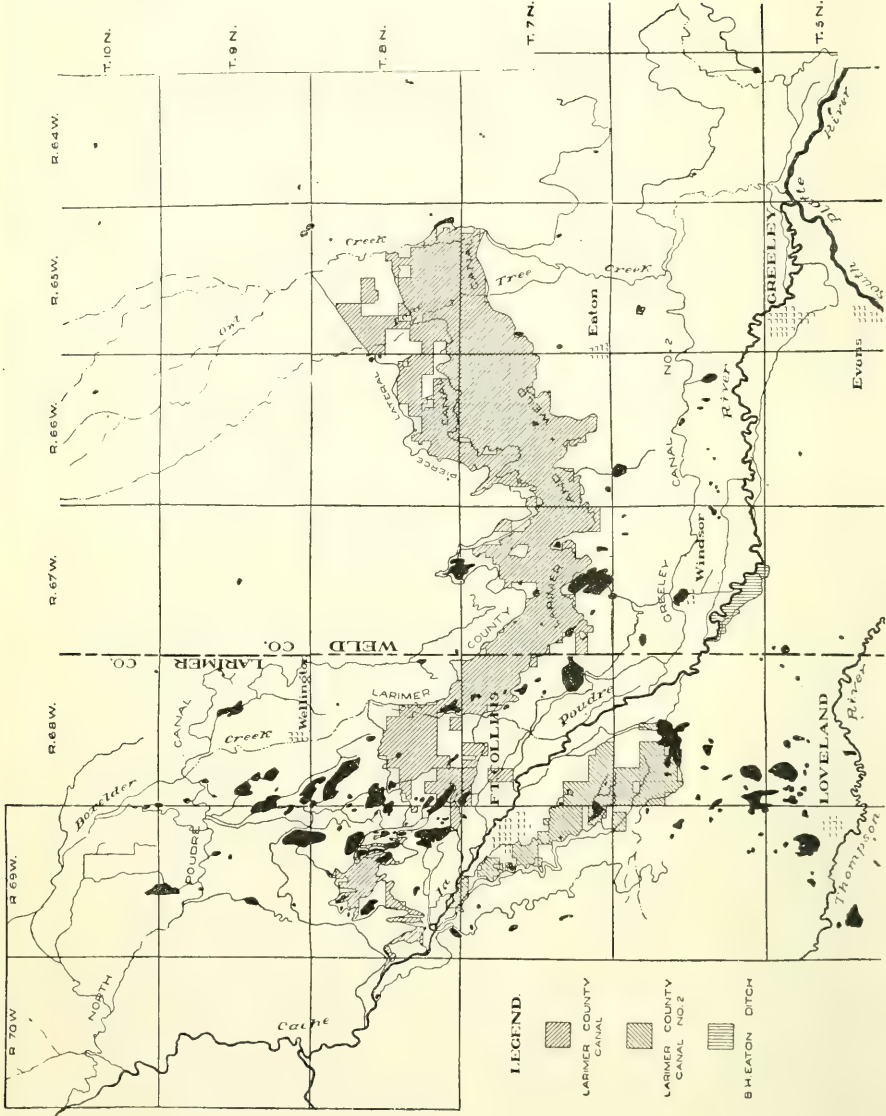
The water rights of the company in the Cache la Poudre are listed on pages 14 and 16. The company also has decrees for appropriations made in other districts, but these are not listed. The owners of rights in the Smith Ditch, with a single exception, exchanged their rights for stock in the company. With this exception the appropriations of the company are owned jointly.

The system of water delivery on the Larimer County Canal is comparatively simple so far as the user is concerned. At any time there is water in the canal for direct irrigation he is entitled to his pro rata share and may obtain it by notifying the ditch rider that he wishes it turned out. The water delivered is measured over rectangular weirs, and the riders carry tables from which the proper depth over the weir may be taken directly. These tables are based on the delivery of 1.677 second-feet, or 40 "farmer's inches," to the share. At this rate the 600 shares of the company require 406 second-feet, and this demand is supplied by a flow of 485 second-feet in the canal. Incidentally this indicates a loss of approximately 16 per cent in the canal. However, the canal carries a full supply only a short time during the season, and deliveries are usually made at the rate of 20 or 30 "farmer's inches" to the share. To determine the depth over the weir for the delivery of less than 40 inches to the share, the number of inches is multiplied by the number of shares to be satisfied and the result is divided by 40. The quotient is the equivalent number of shares on a basis of 40 inches to the share, and the corresponding depth is taken directly from the table.

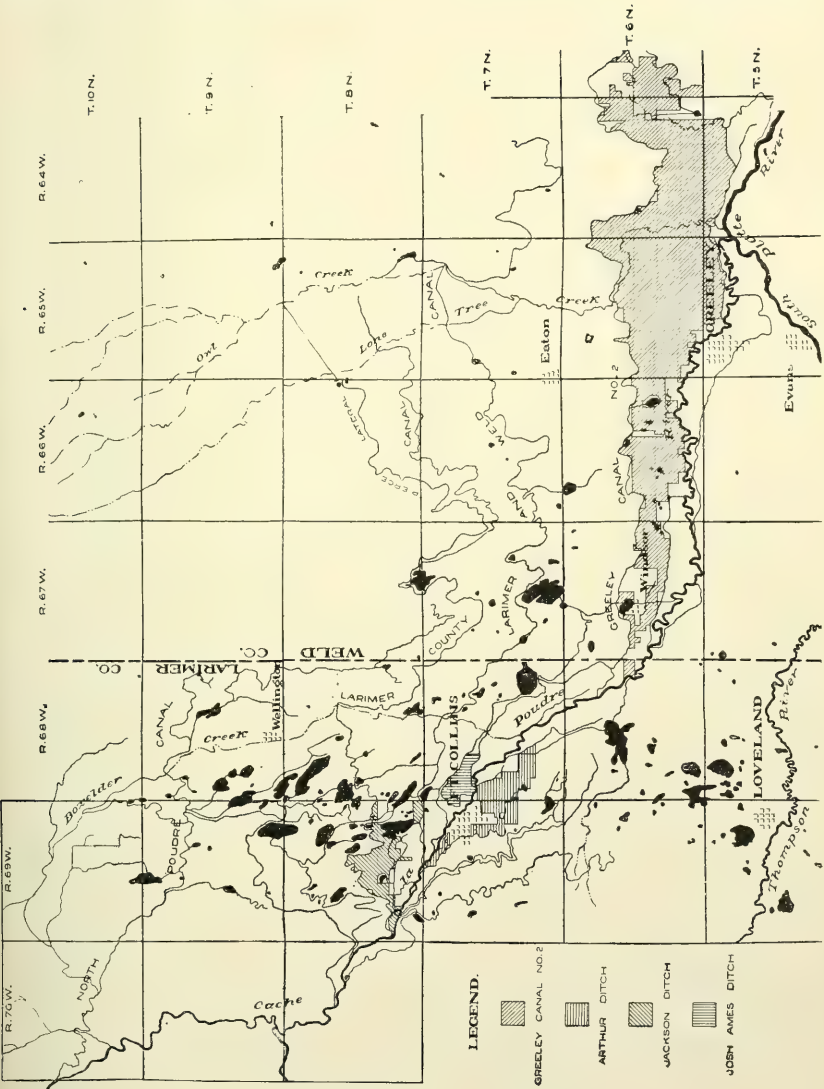
The amount of water to be carried in the canal at various times is determined by the superintendent and the board of directors and depends on the supply in sight and the disposal of it necessary to finish the season in good shape. At the high stage of the river plenty of water is usually received from the mountain ditches, on exchange and on direct appropriations, but as the supply diminishes enough water is held up to insure proper irrigation of late crops, such



AREAS IRRIGATED IN 1916 BY THE LARIMER AND WELD CANAL, THE PLEASANT VALLEY AND LAKE CANAL, THE CHAFFEE DITCH, AND THE OGILVY DITCH.



AREAS IRRIGATED IN 1916 BY THE LARIMER COUNTY CANAL NO. 2 AND THE B. H. EATON DITCH.



AREAS IRRIGATED IN 1916 BY THE GREELEY CANAL NO. 2, THE ARTHUR DITCH, THE JACKSON DITCH, AND THE JOSH AMES DITCH.

as potatoes and sugar beets. At times of extreme shortage runs of 5 to 8 days are made, at intervals of 5 to 8 days, and 20 to 30 inches are delivered to the share.

Records kept include frequent readings of all reservoir gauges, from which the available supply may be determined; records of discharge of the main canal at the head and of the various mountain ditches of the system; records of water delivered to each stockholder, and records of all water received or delivered in exchange. The records of delivery are on cards and show for each user each day of the season the number of shares he drew water on, the rate in inches per share, and the depth over the weir.

GREELEY CANAL NO. 2.

The Greeley Canal No. 2, known also as the Union Colony Canal No. 2, or the Cache la Poudre Canal, was built by the Union Colony at Greeley. Preliminary work was done in 1870 and the first construction was completed in 1871. Enlargements were made in 1874 and 1877. In 1878 the Cache la Poudre Irrigation Co. was organized by the farmers under the canal to take over control from the colony, and a large sum was spent in improving the headworks and in bettering the alignment of the canal. The present company, the New Cache la Poudre Irrigation Co., was organized in 1890 to undertake various improvements of the system. The company has a capital stock of \$100,000 divided into 2,500 shares of a par value of \$40, of which 2,496 have been issued. Each of the original rights is represented by 8 shares of the present company. In 1916 rights sold for \$2,800, which is equivalent to an increase of 900 per cent in value.

The entire cost of operation and ordinary maintenance of the canal has lately been met by charges of the company for carrying reservoir water, and assessments were levied on the stock only for special expenses. Thus in 1916 current expenses were \$6,736, while tolls for carrying reservoir water amounted to \$7,961. The average cost of operation and maintenance is at the rate of approximately 20 cents per acre irrigated.

The main canal heads in section 11, T. 6 N., R. 68 W., and ends 26 miles below at Lone Tree Creek, but an 18-mile extension tails in Crow Creek. At the head of the canal it is 34 feet wide on the bottom, carries water to a depth of 4 feet, and is on a grade of 3.2 feet per mile. The maximum head carried during 1916 and 1917 was 558 second-feet. There are 40 companies owning and operating the larger laterals and the total length of laterals is estimated to exceed 300 miles.

The water rights of the company are shown in the tabulation on page 15, and the area irrigated in 1916 in Plate XII.

The distribution of both river and reservoir water from the Greeley Canal No. 2 is handled in much the same manner as from the Larimer and Weld Canal. The company controls only the main canal and its responsibility ends when the water is delivered to the lateral. Because of its short length the canal is divided into two sections only, each of which is handled by a ditch rider under the direction of the superintendent. Diversions from the canal are made through Powell gates, which may be raised or lowered only by the ditch rider, and the water delivered is measured over weirs. Before the delivery of reservoir water is begun the user may get his pro rata share of the water in the canal by applying to either the rider on the main ditch or the rider on his lateral. After the canal begins carrying reservoir water the small amount of river water received is used to supply reservoir demands and an equivalent credit is accumulated in either the Windsor Reservoir or the Cache la Poudre Reservoir. When a sufficient credit has been accumulated to supply a day's run to each right, each stockholder under the canal is credited with his pro rata share, which will be delivered to him on demand.

Reservoir water is delivered by the company on demand of the user a day in advance, orders received before 1 p. m. being filled the following morning. The unit used is 1 second-foot for a day, and the company charge for carriage is \$1. The secretary of the company is required to keep a record of the reservoir water handled and for this purpose he has a journal, order book, and ledger. All credits of water reported are first entered in the journal, after which they are posted in the ledger. The order book page is designed for a period of 10 days and is divided into columns in which are entered the date, name of user, page of ledger containing his account, a notation to show whether the order was received by telephone or otherwise, name of person giving order, units or "rights" ordered, lateral to which water was to be delivered, and character of order, whether open or for a definite period, after which are 10 columns for noting the units delivered each day. These records are also posted in the ledger, which is in the form below:

Form of reservoir water accounts, Greeley Canal No. 2.

HERMAN SANDERS.

Debit.			Credit.		
Aug. 6.....	68	2.00	Aug. 3. No. 2.....	99	16.50
7.....	68	2.00	15. Windsor.....	98	25.50
* * * * *	*	*	* * * * *	*	*
Sept. 18.....	68	2.00	25. Windsor.....	105	25.50
19.....	68	1.50	(W. Lang)		
		67.50			67.50

On the debit side the number in the second column refers to the page in the order book, and the third column shows the number of units carried. On the credit side the second column shows the source of the water, the last two credits being Windsor Reservoir water rented from W. Lang. The third column carries references to pages in the journal. The last column shows the units credited, and as the charge per unit is \$1, also dollars paid for carriage.

At 1 o'clock each day the secretary begins the preparation of a list of demands for the following day, showing the name of the user, the rights or units ordered, and the lateral to which the water is to be delivered. A copy is furnished to each rider and from it he figures out the amount which he must turn to each lateral the following morning. As in the case of the Larimer and Weld Canal the reservoir from which the supply for a particular day is drawn will depend not so much on the demands for its rights as upon the requirements for the most satisfactory operation of the canal.

THE NORTH POUDBRE CANAL.

Surveys of canals to irrigate the territory now covered by the North Poudre Canal were made in 1878 and 1879 by local men, but they could not raise the funds necessary to carry their projects forward, and nothing came of their efforts. In 1881, F. L. Carter-Cotton and others organized the North Poudre Land, Canal, & Reservoir Co., secured the financial support of the Travelers' Insurance Co., and began work on the canal. By 1884 construction had been completed to Boxelder Creek, but no water could be obtained from the river that year and very little in the 2 years following. In 1887 the promoters quit and control was assumed by the insurance company. This company operated the system until 1896, when it sold out to F. C. Grable. In 1901 the system passed into the possession of the present owner, the North Poudre Irrigation Co. This company was originally capitalized at \$400,000, but in 1913, to absorb the Mountain Supply Ditch Co., the capital was increased to \$500,000, divided into 10,000 shares of a par value of \$50. In 1916 these shares were selling at \$112. Both land and water rights were sold by the company, and with each 80-acre right went 25 shares of the company. Holdings now vary widely and range from 10 to 35 shares for 80 acres.

The company has outstanding over \$500,000 in bonds and short-time obligations of from \$25,000 to \$50,000 have lately been carried from year to year. Regular assessments are levied on the capital stock at the rate of \$5 per share and occasionally an extra assessment is levied for some special purpose. In 1917 the cost of operation and maintenance was about \$27,000, or close to 80 cents per acre irrigated.

The original water supply of the canal was of practically no value and the constant endeavor of the company to build up a reliable supply has resulted in the acquisition of various reservoirs, canals, and rights.

The main canal of the system heads in the North Fork of the Cache la Poudre in section 12, T. 10 N., R. 71 W., and is about 25 miles long, including 4 or 5 miles of natural channel in Campbell Draw. The bottom width at the head is 22 feet, the maximum depth of water carried is 3.3 feet, and the maximum capacity is 200 second-feet. There is comparatively little irrigation from this canal, but it supplies the lower reservoirs of the system from which the distributing laterals extend.

The Scurvin Ditch leaves the main canal a short distance above Campbell Draw and supplies a large area along the Boxelder but above the main canal. It also serves as an intake canal for Reservoir No. 15.

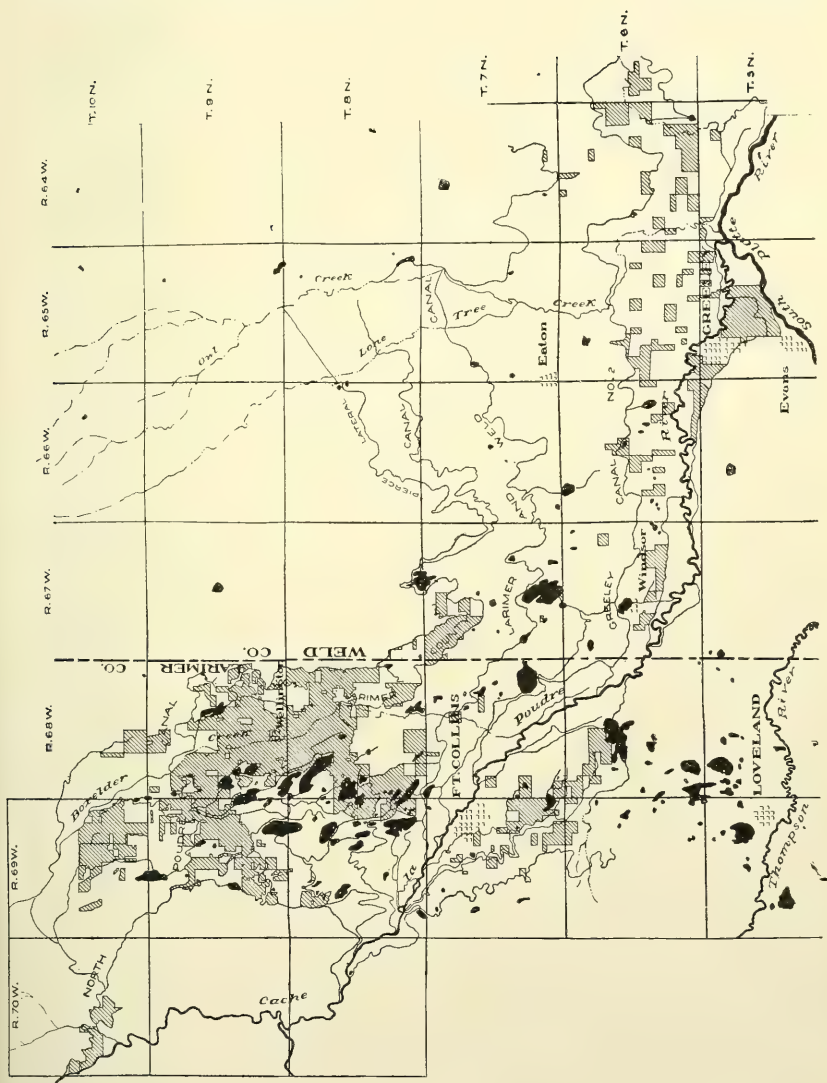
The company is also interested in the Poudre Valley Canal to the extent of a first right to the use of the canal as a carrier both to store water in Reservoirs No. 5 and No. 6 and for direct irrigation of lands just north of Fort Collins.

In addition, the company owns the Michigan Ditch, which diverts water from tributaries of the Michigan River into the Cache la Poudre. Water from this ditch may be used directly through the Poudre Valley canal or in the main canal by exchange.

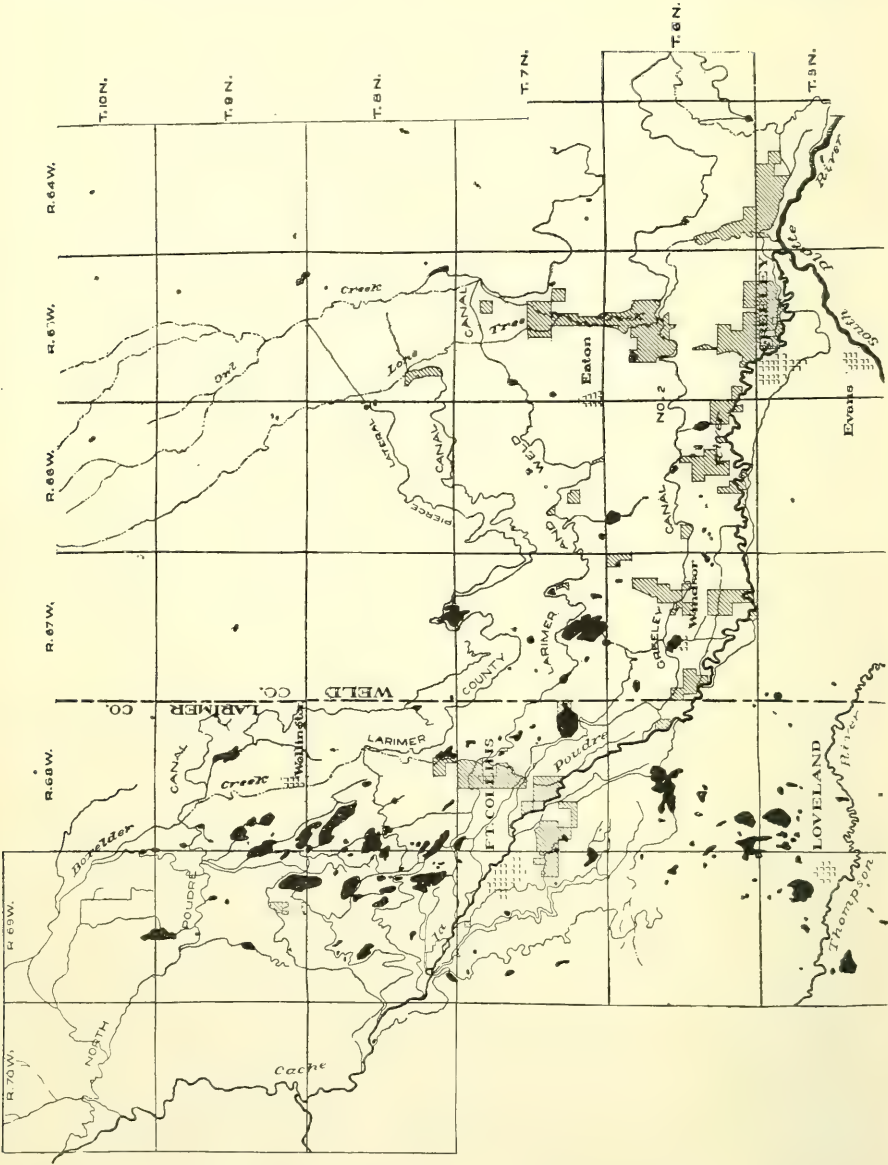
The total storage capacity available for the system is close to 53,000 acre-feet, as is shown by the accompanying list of the company's reservoirs. The most valuable reservoir of the company is Halligan, which is in the bed of the North Fork several miles above the head of the main canal. In addition to commanding all the land irrigated by the system "temporary" storage of direct flow rights in it is permitted by court decree. Reservoir No. 15 derives its value from the fact that it also is above the main canal and commands a large part of the total acreage of the system.

Water stored in Reservoirs No. 5, and No. 6, Fossil Creek Reservoir, and Portner Reservoir can be used only by exchange, but they are essential features of the system. The available supply for the Fossil Creek Reservoir has been such that its filling was practically assured each year. The rights of the North Poudre company in this reservoir are subject, however, to the prior satisfaction of preferred rights aggregating 150,000,000 cubic feet or 3,444 acre feet.

The company is part owner of the Boxelder Ditch & Reservoir Co. and secures several hundred acre-feet of stored water from this source each year.



AREA IRRIGATED IN 1916 BY WATER OF THE NORTH POUDRE IRRIGATION CO. AND BY WATER ON PREFERRED RIGHTS IN FOSSIL CREEK RESERVOIR.



IRRIGATED ACREAGE ON WHICH SEEPAGE WAS THE MAIN WATER SUPPLY IN 1916.

Under an old agreement with B. G. Eaton for carrying water from Worster for certain of his lands under the North Poudre Canal the company secures 160 acre-feet of stored water from that reservoir.

Reservoirs of the North Poudre Irrigation Co.

Reservoir.	Capacity (acre-feet).	Reservoir.	Capacity (acre-feet).
No. 1.....	445	Tenney.....	345
No. 2.....	3,880	Mountain Supply No. 2.....	150
No. 3.....	2,870	Bubble.....	225
No. 4.....	2,795	Cameron Pass.....	815
No. 5.....	5,740	Halligan.....	6,428
No. 6.....	10,215	No. 15.....	5,510
Caverly.....	170	Fossil Creek.....	12,650
Stuchell.....	170	Portner.....	595
Coal Creek.....	4,095		

The water rights of the company are shown in the tabulations on pages 14 and 16. The area irrigated in 1916 is shown on Plate XIII. No dependence could be placed in the original appropriation of the canal and the necessity for a more reliable supply accounts for the large number of transferred rights. With the exception of the William Calloway right and the rights of the Brown ditches, these appropriations are owned outright by the company. The former is limited in use to a certain tract and the latter are carried for the use of individuals under a perpetual contract. To permit a better use the transferred rights owned by the company may be stored temporarily in Halligan Reservoir until a sufficient amount has been accumulated for an economical head for the main canal.

The system of water delivery under the North Poudre Canal is different from that of any other canal in the valley. At the beginning of the season the superintendent determines the amount of water in storage and estimates the amount in sight on direct appropriations. On this basis an allotment is made which in average years is close to 125,000 cubic feet per share. This water is delivered upon demand at any time during the season and at any rate, subject of course to certain requirements of operation. To discourage extensive growing of crops requiring late irrigation, heavy deductions of credits are made for absorption losses as the season progresses. Water credits remaining on June 1 are reduced by 10 per cent; those remaining on July 1 are reduced by 25 per cent, and on August 1 a reduction of 50 per cent is made. Under this system, if the farmer starts the season with an allotment of 100,000 cubic feet per share and uses no water until August 1, he will then be entitled to only 33,700 cubic feet per share.

When the farmer wishes to draw water he notifies the ditch rider or the office of the company in Wellington the day before and states

the size of the head he desires turned out. The riders meet every morning at the office, list the demands, and compare them with the credits remaining. Then they cover their "beats" and set the various gates to deliver the amounts demanded. The water is measured over wooden rectangular weirs and the proper depth over the weir is determined from tables which show for each size of weir the discharge in Colorado statute inches, cubic feet per hour, and cubic feet per 24 hours. The rider's records include a daily report and a separate delivery account for each user. The daily report of deliveries shows the name of the farmer drawing; size of weir; depth over weir; hours run and total cubic feet delivered during the day, the day being reckoned from midnight to midnight. In the record of delivery kept by the rider each user is given a separate account in which is entered a complete record of all water drawn. In addition there is kept at the office at Wellington a water ledger containing a record of all credits and of all deliveries as compiled from the daily reports of ditch riders. From this ledger the state of any account can be determined at a glance.

GROSS DUTY FOR CANALS.

To serve as a basis for computing the duty of water measured at the heads of canals of the valley, the total area and the crops irrigated by each canal in 1916 and 1917 are shown in Table 9. Each canal is credited with all the land and crops irrigated by it, either alone or in combination with other canals. Overlapping of areas served by two or more canals, is the cause of considerable duplication of acreage in the table. The effect of the war may be noted in the large increase in food crops as well as in the appreciable increase in the total acreage irrigated.

In Tables 10 and 11 the water used by the canals of the valley in 1916 and 1917 is shown with a proper segregation of direct flow and stored water. Under the head of direct flow has been included water on direct appropriations, foreign water not stored, and certain exchange water. Thus, Windsor Reservoir water delivered to Greeley Canal No. 2 in payment for No. 2 water taken above in exchange is classed as direct flow. On the other hand river water taken by the Larimer County Canal in exchange for water in Lindenmeier Lake is classed as stored water.

TABLE 9. Total acreage and crops irrigated by the canals of the valley in 1916 and 1917.

1916.

Canal.	Alfalfa.	Grain.	Sugar beets.	Potatoes.	Beans.	Corn.	Peas.	Garden and orchard.	Native hay.	Pasture.	Miscellaneous.	Total.
North Poudre Canal ¹	12,932	9,281	3,687	105	1,441	281	103	175	348	751	488	29,592
Poudre Valley Canal ²	340	118	6	.....	.....	1	.....	6	74	120	.....	665
Pleasant Valley and Lake Canal.....	3,590	1,293	966	.....	.....	178	.....	321	127	359	82	6,916
Larimer County Canal.....	19,305	10,247	7,377	4,216	1,978	867	607	97	91	1,849	522	47,156
Jackson Ditch.....	917	577	247	.....	.....	77	.....	98	4	326	11	2,257
Little Cache La Poudre Ditch ³	405	285	478	.....	4	1	.....	13	32	155	195	1,568
Taylor and Gill Ditch.....	120	27	135	.....	.....	6	.....	78	.....	49	8	423
Larimer County Canal No. 2.....	3,549	1,028	1,564	.....	5	101	.....	161	.....	146	35	6,589
New Mercer Canal.....	2,924	670	1,085	.....	.....	103	.....	203	2	160	39	5,183
Arthur Ditch.....	1,203	455	442	.....	6	2	.....	62	.....	42	33	2,245
Larimer and Weld Canal.....	21,510	10,376	10,805	6,254	3,821	531	441	.....	.....	1,329	877	55,944
Josh Ames Ditch.....	270	124	387	.....	20	.....	.....	4	.....	111	71	987
Pioneer Ditch.....	100	.....	.....	.....	.....	36	.....	.....	.....	31	.....	167
Lake Canal.....	2,858	1,054	2,217	39	162	6	40	6	.....	870	57	7,519
Coy Ditch.....	98	24	41	.....	.....	21	.....	.....	.....	38	.....	222
Chaffee Ditch.....	125	92	92	.....	.....	.....	.....	.....	.....	144	.....	453
Boxelder Ditch.....	661	361	489	.....	8	.....	.....	2	.....	168	15	1,704
Greeley Canal No. 2.....	12,365	4,239	8,054	2,174	3,372	940	939	193	.....	1,116	779	33,978
Whitney Ditch.....	744	683	1,062	.....	82	49	44	.....	241	963	39	3,907
B. H. Eaton Ditch.....	166	175	439	.....	32	.....	18	.....	.....	453	9	1,292
Jones Ditch.....	53	164	161	.....	66	.....	29	.....	73	118	13	677
Greeley Canal No. 3.....	615	552	1,119	.....	248	144	55	.....	.....	482	211	3,427
Boyd and Freeman Ditch.....	62	44	255	.....	16	.....	4	.....	17	212	.....	610
Ogilvy Ditch.....	1,006	294	365	88	553	155	.....	.....	.....	.....	21	2,482
Seepage.....	5,001	2,415	3,476	996	1,174	123	261	.....	.....	909	806	15,161

1917.

North Poudre Canal ¹	13,807	10,985	3,941	214	2,833	867	.....	155	184	221	348	33,550
Poudre Valley Canal ²	326	175	29	.....	6	4	.....	6	74	45	.....	665
Pleasant Valley and Lake Canal.....	3,437	2,049	837	.....	25	104	.....	267	86	307	231	7,343
Larimer County Canal.....	17,012	10,194	5,221	7,227	5,048	475	137	106	91	1,561	747	47,819
Jackson Ditch.....	765	744	247	.....	7	61	.....	98	16	305	18	2,261
Little Cache La Poudre Ditch ³	389	366	420	.....	18	26	.....	13	29	143	139	1,543
Taylor and Gill Ditch.....	93	40	140	.....	.....	17	.....	80	.....	35	80	423
Larimer County Canal No. 2.....	3,564	1,077	1,583	3	17	92	.....	156	.....	134	26	6,652
New Mercer Canal.....	2,615	1,043	1,104	1	27	109	.....	197	2	97	41	5,236
Arthur Ditch.....	1,215	471	425	.....	.....	.....	.....	159	.....	10	48	2,329
Larimer and Weld Canal.....	18,902	10,884	7,175	10,888	6,569	872	54	7	323	1,325	985	57,984
Josh Ames Ditch.....	230	282	262	.....	8	63	.....	3	.....	58	33	939
Pioneer Ditch.....	104	.....	20	.....	.....	.....	.....	.....	.....	28	.....	132
Lake Canal.....	2,672	1,484	1,876	148	145	10	.....	7	.....	727	27	7,096
Coy Ditch.....	102	4	63	.....	.....	30	.....	.....	.....	24	.....	223
Chaffee Ditch.....	166	70	138	.....	.....	.....	.....	.....	.....	79	.....	453
Boxelder Ditch.....	760	383	357	.....	21	.....	.....	2	.....	181	.....	1,704
Greeley Canal No. 2.....	10,996	5,563	4,379	5,158	5,262	1,104	58	38	155	992	847	34,483
Whitney Ditch.....	778	780	518	260	237	44	.....	.....	241	950	181	3,989
B. H. Eaton Ditch.....	200	271	77	30	122	.....	.....	.....	.....	414	167	1,281
Jones Ditch.....	60	130	123	71	104	.....	.....	.....	73	114	2	677
Greeley Canal No. 3.....	633	360	695	201	441	166	99	.....	.....	444	351	3,390
Boyd and Freeman Ditch.....	70	94	105	32	46	10	.....	.....	17	213	64	651
Ogilvy Ditch.....	938	308	256	218	538	220	.....	.....	.....	8	24	2,510
Seepage.....	4,740	3,232	2,440	1,963	1,949	276	41	4	.....	923	464	16,032

¹ The acreage here given includes only that under the main canal. The total area irrigated wholly or in part by water of the North Poudre Irrigation Co. (including preferred rights in Fossil Creek Reservoir), was 46,222 acres in 1916 and 50,203 acres in 1917.

² Part of the stock of this ditch is owned by the Larimer and Weld Reservoir Co., and the water represented is rented to the Larimer and Weld Irrigation Co. It is taken into the Larimer and Weld Canal through Dry Creek and is applied to all lands under that canal. The area covered by this water is not included here.

³ The acreage given does not include lands north of Fort Collins irrigated from laterals of the North Poudre Canal with water brought through this canal.

TABLE 10.—*Water, in acre-feet, used by the canals of the valley in 1916.*

DIRECT FLOW.

	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Total.
North Poudre Canal.....	870	1,760	6,583	4,001	2,245	710	0	16,169
Poudre Valley Canal.....	0	697	585	486	748	0	0	2,516
Pleasant Valley and Lake Canal.....	1,357	3,253	4,341	2,977	2,874	1,885	0	16,687
Larimer County Canal.....	0	5,398	22,147	11,971	8,482	1,878	0	49,876
Jackson Ditch.....	77	788	1,158	1,305	680	374	0	4,382
Little Cache la Poudre Ditch.....	0	359	737	1,058	922	0	0	3,076
Taylor and Gill Ditch.....	365	466	794	786	740	590	276	4,017
Larimer County Canal No. 2.....	154	3,562	4,455	2,179	691	29	0	11,070
New Mercer Canal.....	31	2,016	2,147	2,059	1,296	342	0	7,891
Arthur Ditch.....	491	1,663	1,264	1,703	737	177	79	6,114
Larimer and Weld Canal.....	1,420	14,704	35,482	10,316	4,439	805	0	67,166
Josh Ames Ditch.....	28	43	451	576	368	17	0	1,483
Lake Canal.....	0	4,035	5,116	1,992	304	0	0	11,447
Coy Ditch.....	0	105	114	366	164	0	0	749
Chaffee Ditch.....	0	277	64	351	255	0	0	947
Boxelder Ditch.....	0	514	1,042	948	371	40	0	2,915
Greeley Canal No. 2.....	1,681	16,431	20,010	11,201	3,136	2,449	0	54,908
Whitney Ditch.....	109	451	1,086	1,743	1,587	984	64	6,024
B. H. Eaton Ditch.....	169	277	579	1,115	411	278	0	2,829
Jones Ditch.....	0	23	312	455	656	94	0	1,540
Greeley Canal No. 3.....	1,691	2,973	3,958	4,555	3,130	3,215	438	19,960
Boyd and Freeman Ditch.....	0	0	408	421	382	168	0	1,379
Ogilvy Ditch.....	720	2,495	2,256	2,197	2,307	1,497	0	11,472
Total.....	9,163	62,290	115,089	64,761	36,925	15,532	857	304,617

STORAGE.

	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Total.	Grand total.
North Poudre Canal.....	353	5,337	5,147	10,334	3,331	686	0	25,188	41,357
Poudre Valley Canal.....	0	0	0	0	0	0	0	0	2,516
Pleasant Valley and Lake Canal.....	0	0	0	598	206	17	0	821	17,508
Larimer County Canal.....	0	1,489	1,366	6,310	7,598	5,348	0	22,111	71,987
Jackson Ditch.....	0	0	0	0	0	0	0	0	4,382
Little Cache la Poudre Ditch.....	0	0	0	0	0	0	0	0	3,076
Taylor and Gill Ditch.....	0	0	0	0	0	0	0	0	4,017
Larimer County Canal No. 2.....	0	0	0	148	64	39	0	251	11,321
New Mercer Canal.....	0	0	0	0	91	72	0	163	8,054
Arthur Ditch.....	0	0	0	0	0	23	0	23	6,137
Larimer and Weld Canal.....	0	0	126	5,432	12,117	6,251	0	23,926	91,092
Josh Ames Ditch.....	0	0	0	0	0	0	0	0	1,483
Lake Canal.....	0	0	0	564	1,190	830	0	2,584	14,031
Coy Ditch.....	0	0	0	0	0	0	0	0	749
Chaffee Ditch.....	0	0	0	0	0	0	0	0	947
Boxelder Ditch.....	0	0	0	0	0	0	0	0	2,915
Greeley Canal No. 2.....	0	0	0	3,169	6,747	3,542	0	13,458	68,366
Whitney Ditch.....	0	0	0	0	0	0	0	0	6,024
B. H. Eaton Ditch.....	0	0	0	0	0	0	0	0	2,829
Jones Ditch.....	0	0	0	0	0	0	0	0	1,540
Greeley Canal No. 3.....	0	0	0	257	584	409	0	1,250	21,210
Boyd and Freeman Ditch.....	0	0	0	0	0	0	0	0	1,379
Ogilvy Ditch.....	0	152	0	286	221	156	0	815	12,287
Total.....	353	6,978	6,639	27,098	32,149	17,373	0	90,590	395,207

TABLE 11.—*Water in acre-feet used by the canals of the valley in 1917.*

DIRECT FLOW.

	April.	May.	June.	July.	August.	September.	October.	Total.
North Poudre Canal.....	0	318	8,588	10,069	1,370	400	0	20,745
Poudre Valley Canal.....	0	0	472	1,165	88	51	0	1,776
Pleasant Valley and Lake Canal.....	453	202	4,945	6,171	3,119	1,669	0	16,559
Larimer County Canal.....	0	8,087	22,626	25,386	6,672	1,921	0	64,692
Jackson Ditch.....	0	86	1,261	1,645	1,079	558	15	4,644
Little Cache la Poudre Ditch ¹	0	0	1,026	505	893	204	0	2,628
Taylor and Gill Ditch.....	264	231	560	810	784	560	0	3,209
Larimer County Canal No. 2.....	0	0	4,096	6,795	288	43	0	11,222
New Mercer Canal.....	0	47	3,075	3,592	1,214	42	0	7,970
Arthur Ditch.....	0	281	1,495	2,241	453	56	0	4,526
Larimer and Weld Canal ²	762	2,188	31,957	28,983	2,996	1,003	0	67,889
Josh Ames Ditch.....	0	0	178	698	532	0	0	1,408
Lake Canal.....	0	213	5,454	6,156	158	0	0	11,981
Coy Ditch.....	0	0	0	204	363	41	0	608
Chaffee Ditch.....	0	0	286	514	198	0	0	998
Boxelder Ditch.....	0	0	1,272	1,255	1,645	991	0	5,163
Greeley Canal No. 2.....	0	2,164	18,349	27,132	4,687	1,051	0	53,383
Whitney Ditch.....	0	0	843	1,478	1,635	997	0	4,953
B. H. Eaton Ditch.....	0	329	1,071	1,261	989	477	21	4,148
Jones Ditch.....	0	0	85	29	381	457	0	952
Greeley Canal No. 3.....	275	946	2,899	4,544	3,170	2,653	0	14,487
Boyd and Freeman Ditch.....	0	96	134	354	538	254	0	1,376
Ogilvy Ditch.....	0	686	2,297	3,284	3,212	2,090	11	11,580
Total.....	1,754	15,874	112,969	134,271	36,464	15,518	47	316,897

STORAGE.

	April.	May.	June.	July.	August.	September.	October.	Total.	Grand total.
North Poudre Canal.....	0	182	1,250	9,512	13,192	4,818	0	28,954	49,699
Poudre Valley Canal.....	0	0	0	0	0	0	0	0	1,776
Pleasant Valley and Lake Canal.....	0	0	0	0	376	276	0	652	17,211
Larimer County Canal.....	0	0	1,108	2,511	13,883	1,772	0	19,274	83,966
Jackson Ditch.....	0	0	0	0	0	0	0	0	4,644
Little Cache la Poudre Ditch ¹	0	0	0	0	0	0	0	0	2,628
Taylor and Gill Ditch.....	0	0	0	0	0	0	0	0	3,209
Larimer County Canal No. 2.....	0	0	0	0	108	78	0	186	11,408
New Mercer Canal.....	0	0	0	0	0	191	0	191	8,161
Arthur Ditch.....	0	0	0	0	0	17	0	17	4,543
Larimer and Weld Canal ²	0	0	0	1,607	20,676	7,264	0	29,547	97,436
Josh Ames Ditch.....	0	0	0	0	0	0	0	0	1,408
Lake Canal.....	0	0	0	0	1,538	510	0	2,048	14,029
Coy Ditch.....	0	0	0	0	0	0	0	0	608
Chaffee Ditch.....	0	0	0	0	0	0	0	0	998
Boxelder Ditch.....	0	0	0	0	0	0	0	0	5,163
Greeley Canal No. 2.....	0	0	0	0	9,141	5,476	0	14,617	68,000
Whitney Ditch.....	0	0	0	0	0	0	0	0	4,953
B. H. Eaton Ditch.....	0	0	0	0	0	0	0	0	4,148
Jones Ditch.....	0	0	0	0	0	0	0	0	952
Greeley Canal No. 3.....	0	0	0	0	1,021	393	0	1,414	15,901
Boyd and Freeman Ditch.....	0	0	0	0	0	0	0	0	1,376
Ogilvy Ditch.....	0	0	0	83	289	95	0	467	12,047
Total.....	0	182	2,358	13,713	60,224	20,890	0	97,367	414,264

¹ Use under Little Cache la Poudre does not include amount delivered to Dry Creek on rights owned by Larimer & Weld Reservoir Co.

² Reservoir water used in July by Larimer and Weld Canal was advanced to canal by Windsor Reservoir to be paid from direct flow later.

The gross duty for the canals of the valley by months and for the year, for both direct flow and storage as shown in Tables 12 and 13, is derived from Tables 9, 10, and 11. The lowest duty is shown by the ditches with old rights watering the bottoms along the river. However, a considerable part of the water carried by them is wasted directly back into the river by laterals and the actual require-

ments of the land under them are much less than the duty shown would indicate. The apparent high duty under the North Poudre Canal in 1916 was due to a short supply, the original allotment of 125,000 cubic feet per share for that year being reduced to 100,000 cubic feet in the latter part of the season. In the majority of cases, however, the duty fairly indicates the requirements of the land under the canal under the present system of cropping.

TABLE 12.—*Monthly and annual gross duty of water in acre-feet per acre under canals of the valley in 1916.*

DIRECT FLOW.

	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Total
North Poudre Canal.....	0.03	0.06	0.22	0.14	0.08	0.02	0.00	0.55
Poudre Valley Canal.....	.00	1.05	.88	.73	1.12	.00	.00	3.78
Pleasant Valley & Lake Canal.....	.20	.47	.63	.43	.42	.27	.00	2.41
Larimer County Canal.....	.00	.11	.47	.25	.18	.04	.00	1.05
Jackson Ditch.....	.03	.35	.51	.58	.30	.17	.00	1.94
Little Cache la Poudre Ditch.....	.00	.23	.47	.67	.59	.00	.00	1.95
Taylor and Gill Ditch.....	.86	1.10	1.88	1.86	1.75	1.39	.65	9.50
Larimer County Canal No. 2.....	.02	.54	.68	.33	.10	.00+	.00	1.63
New Mercer Canal.....	.01	.39	.41	.40	.25	.07	.00	1.52
Arthur Ditch.....	.22	.74	.56	.76	.33	.08	.04	2.72
Larimer and Weld Canal.....	.03	.26	.63	.18	.08	.01	.00	1.20
Josh Ames Ditch.....	.03	.04	.46	.58	.37	.02	.00	1.50
Lake Canal.....	.00	.55	.70	.27	.04	.00	.00	1.56
Coy Ditch.....	.00	.47	.51	1.65	.74	.00	.00	3.37
Chaffee Ditch.....	.00	.61	.14	.77	.56	.00	.00	2.09
Boxelder Ditch.....	.00	.30	.61	.56	.22	.02	.00	1.71
Greeley Canal No. 2.....	.05	.48	.59	.33	.09	.07	.00	1.62
Whitney Ditch.....	.03	.12	.28	.45	.41	.25	.02	1.54
B. H. Eaton Ditch.....	.13	.21	.45	.86	.32	.22	.00	2.19
Jones Ditch.....	.00	.03	.46	.67	.97	.14	.00	2.27
Greeley Canal No. 3.....	.49	.87	1.15	1.33	.91	.94	.13	5.82
Boyd and Freeman Ditch.....	.00	.00	.67	.69	.63	.28	.00	2.26
Ogilvy Ditch.....	.29	1.01	.91	.89	.93	.60	.00	4.62
Average ¹	.04	.30	.55	.31	.18	.07	.00+	1.45

¹ Based on a total area of approximately 210,000 acres irrigated by the canals listed.

STORED WATER.

	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Total	Grand total.
North Poudre Canal.....	0.01	0.18	0.17	0.35	0.11	0.02	0.00	0.85	1.40
Poudre Valley Canal.....	.00	.00	.00	.00	.00	.00	.00	.00	3.78
Pleasant Valley & Lake Canal.....	.00	.00	.00	.09	.03	.00+	.00	.12	2.53
Larimer County Canal.....	.00	.03	.03	.13	.16	.11	.00	.47	1.53
Jackson Ditch.....	.00	.00	.00	.00	.00	.00	.00	.00	1.94
Little Cache la Poudre Ditch.....	.00	.00	.00	.00	.00	.00	.00	.00	1.96
Taylor and Gill Ditch.....	.00	.00	.00	.00	.00	.00	.00	.00	9.50
Larimer County Canal No. 2.....	.00	.00	.00	.02	.01	.01	.00	.04	1.72
New Mercer Canal.....	.00	.00	.00	.00	.02	.01	.00	.03	1.55
Arthur Ditch.....	.00	.00	.00	.00	.00	.01	.00	.01	2.73
Larimer and Weld Canal.....	.00	.00	.00+	.10	.22	.11	.00	.43	1.63
Josh Ames Ditch.....	.00	.00	.00	.00	.00	.00	.00	.00	1.50
Lake Canal.....	.00	.00	.00	.08	.16	.11	.00	.35	1.92
Coy Ditch.....	.00	.00	.00	.00	.00	.00	.00	.00	3.37
Chaffee Ditch.....	.00	.00	.00	.00	.00	.00	.00	.00	2.09
Boxelder Ditch.....	.00	.00	.00	.00	.00	.00	.00	.00	1.71
Greeley Canal No. 2.....	.00	.00	.00	.09	.20	.10	.00	.40	2.01
Whitney Ditch.....	.00	.00	.00	.00	.00	.00	.00	.00	1.54
B. H. Eaton Ditch.....	.00	.00	.00	.00	.00	.00	.00	.00	2.19
Jones Ditch.....	.00	.00	.00	.00	.00	.00	.00	.00	2.27
Greeley Canal No. 3.....	.00	.00	.00	.07	.17	.12	.00	.36	6.19
Boyd and Freeman Ditch.....	.00	.00	.00	.00	.00	.00	.00	.00	2.26
Ogilvy Ditch.....	.00	.06	.00	.12	.09	.06	.00	.33	4.95
Average ¹	.00	.03	.03	.13	.15	.08	.00	.43	1.88

¹ Based on a total area of approximately 210,000 acres irrigated by the canals listed.

TABLE 13.—*Monthly and annual gross duty of water in acre-feet per acre under canals of the valley in 1917.*

DIRECT FLOW.

	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Total.
North Poudre Canal.....	0	0.01	0.26	0.30	0.04	0.01	0	0.62
Poudre Valley Canal.....	0	0	.71	1.75	.13	.08	0	2.67
Pleasant Valley and Lake Canal.....	0.06	.03	.67	.84	.42	.23	0	2.26
Larimer County Canal.....	0	.17	.47	.53	.14	.04	0	1.35
Jackson Ditch.....	0	.04	.56	.73	.48	.25	0.01	2.05
Little Cache la Poudre Ditch.....	0	0	.66	.33	.58	.13	0	1.70
Taylor and Gill Ditch.....	.62	.55	1.32	1.91	1.85	1.32	0	7.59
Larimer County Canal No. 2.....	0	0	.62	1.02	.04	.01	0	1.69
New Mercer Canal.....	0	.01	.59	.69	.23	.01	0	1.52
Arthur Ditch.....	0	.12	.64	.96	.19	.02	0	1.94
Larimer and Weld Canal.....	.01	.04	.55	.50	.05	.02	0	1.17
Josh Ames Ditch.....	0	0	.19	.74	.57	0	0	1.50
Lake Canal.....	0	.03	.77	.87	.02	0	0	1.69
Coy Ditch.....	0	0	0	.91	1.63	.18	0	2.73
Chaffee Ditch.....	0	0	.63	1.13	.44	0	0	2.20
Boxelder Ditch.....	0	0	.75	.74	.97	.58	0	3.03
Greeley Canal No. 2.....	0	.06	.53	.79	.14	.03	0	1.55
Whitney Ditch.....	0	0	.21	.37	.41	.25	0	1.24
B. H. Eaton Ditch.....	0	.26	.84	.98	.77	.37	.02	3.24
Jones Ditch.....	0	0	.13	.04	.56	.68	0	1.41
Greeley Canal No. 3.....	.08	.28	.86	1.34	.94	.78	0	4.27
Boyd and Freeman Ditch.....	0	.15	.21	.54	.83	.39	0	2.11
Ogilvy Ditch.....	0	.27	.92	1.31	1.28	.83	0	4.61
Average ¹	.01	.07	.52	.62	.17	.07	0	1.46

STORED WATER.

	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Total.	Grand total.
North Poudre Canal.....	0	0.01	0.04	0.28	0.39	0.14	0	0.86	1.48
Poudre Valley Canal.....	0	0	0	0	0	0	0	0	2.67
Pleasant Valley and Lake Canal.....	0	0	0	0	.05	.04	0	.09	2.34
Larimer County Canal.....	0	0	.02	.05	.29	.04	0	.40	1.76
Jackson Ditch.....	0	0	0	0	0	0	0	0	2.05
Little Cache la Poudre Ditch.....	0	0	0	0	0	0	0	0	1.70
Taylor and Gill Ditch.....	0	0	0	0	0	0	0	0	7.59
Larimer County Canal No. 2.....	0	0	0	0	.02	.01	0	.03	1.71
New Mercer Canal.....	0	0	0	0	0	.04	0	.04	1.56
Arthur Ditch.....	0	0	0	0	0	.01	0	.01	1.96
Larimer and Weld Canal.....	0	0	0	.03	.35	.13	0	.51	1.68
Josh Ames Ditch.....	0	0	0	0	0	0	0	0	1.50
Lake Canal.....	0	0	0	0	.22	.07	0	.29	1.98
Coy Ditch.....	0	0	0	0	0	0	0	0	2.73
Chaffee Ditch.....	0	0	0	0	0	0	0	0	2.20
Boxelder Ditch.....	0	0	0	0	0	0	0	0	3.03
Greeley Canal No. 2.....	0	0	0	0	.27	.16	0	.42	1.97
Whitney Ditch.....	0	0	0	0	0	0	0	0	1.24
B. H. Eaton Ditch.....	0	0	0	0	0	0	0	0	3.24
Jones Ditch.....	0	0	0	0	0	0	0	0	1.41
Greeley Canal No. 3.....	0	0	0	0	.30	.12	0	.42	4.69
Boyd and Freeman Ditch.....	0	0	0	0	0	0	0	0	2.11
Ogilvy Ditch.....	0	0	0	.03	.12	.04	0	.19	4.80
Average ¹	0	0	.01	.06	.23	.10	0	.45	1.91

¹ Based on a total area of approximately 217,000 acres irrigated by the canals listed.

TABLE 14.—*Duty measured at the heads of laterals.*

1916.

Lateral.	Canal.	Days run.	Acres irrigated.	Acres used.	Acres per acre.	Acres per acre, entire canal.	Ratio.
Cactus Hill.....	North Poudre Canal.....						
No. 2 Outlet.....	do.....	129	2,935	2,745	0.93	1.40	66
Crane.....	Larimer County Canal.....	81	1,219	1,273	1.04	1.53	67
Crosscut.....	do.....	104	2,170	3,791	1.75	1.53	114
Bliss.....	Pierce Lateral of Larimer County Canal.....	105	1,123	1,151	1.03	1.53	67
Mitchell.....	Jackson.....	126	444	1,128	2.54	1.94	131
Dixon Canyon.....	Little Cache la Poudre.....	28	129	79	.61	1.96	31
Town.....	Larimer and Weld Canal.....	106	4,092	7,678	1.87	1.63	115
	Lake Canal.....						
Total and average.	.....		12, 112	17, 845	1.47	1.58	93

1917.

Cactus Hill.....	North Poudre Canal.....	108	1,870	2,667	1.43	1.48	97
No. 2 Outlet.....	do.....	110	2,935	3,579	1.22	1.48	82
Crane.....	Larimer County Canal.....	106	1,210	1,850	1.53	1.76	87
Crosscut.....	do.....	115	2,169	4,634	2.12	1.76	120
Bliss.....	Pierce Lateral of Larimer County Canal.....	115	1,163	2,017	1.73	1.76	98
	Jackson.....	113	444	1,233	2.78	2.05	136
Mitchell.....	Little Cache la Poudre.....	27	83	58	.70	1.70	41
Dixon Canyon.....	Larimer County Canal, No. 2.....	44	1,066	1,484	1.39	1.71	81
Town.....	Larimer and Weld Canal.....	105	4,166	9,519	2.29	1.68	136
	Lake Canal.....	74	575	1,234	2.15	1.98	109
Total and average.	.....		15, 681	28, 275	1.80	1.68	107

DUTY AT HEADS OF LATERALS.

During the investigation, records of discharge and acreage irrigated were obtained for a number of laterals to afford a comparison of the duty measured at the head of the lateral with the duty measured at the head of the canal. The results of the measurements, together with the comparisons, are shown in Table 14. These erratic variations may be occasioned by a number of conditions. There are no restrictions on holdings of shares of ditch stock with reference to the acreage irrigated, and under a single lateral the ratio between the two may be as much as 20 per cent above or below the average ratio for the entire canal. Such a lateral would be entitled on its shares to an amount of water 20 per cent above the average for the entire canal. What is true of canal shares is true to a greater degree of reservoir rights carried in the canals which act as common carriers, for water from this source is limited only by the number of rights which can not be bought, rented, or borrowed. A considerable part of the variation may be attributed to systems of distribution to laterals. A few of the canals, including the Little Cache la Poudre and the Jackson ditches, have no measuring devices for distribution

and depend on the judgment of the rider to make a fair division. No man's judgment is infallible, and it is to be expected that considerable errors must result. Even where weirs are used the installation is often faulty enough to produce a difference of 25 per cent between the amount supposed to be delivered and the amount actually delivered. In addition the kinds of crops grown no doubt account for some of the variation. Because of high prices and war needs the acreage of potatoes under 2 or 3 laterals in 1917 was increased at a much greater rate than for the entire canal. This resulted in a proportionately lower duty for the lateral. Under other laterals the switch was from alfalfa to wheat, and in these cases the duty was correspondingly higher.

ABSORPTION LOSSES IN CANALS.

Conditions are such in the Cache la Poudre Valley that there are few canals in which sections suitable for measuring absorption losses may be found. The quantities to be determined are small and the methods of measurement have their limitations, so conditions are best when the loss may be determined for a uniform head for a long period over a stretch of canal into which there is no drainage and from which there is no outflow. Almost without exception, distributing canals could not be used on account of the many diversions, beginning almost at the headgate. Canals carrying water for storage were usually unsatisfactory on account of fluctuating heads, uncertain supply, or ice conditions. However, fairly satisfactory measurements were obtained on the Poudre Valley, North Poudre, and Larimer and Weld Canals.

The measurement on the Poudre Valley Canal was made in the latter part of May, 1917, and included a section of the canal from the head to a station a short distance above the Dry Creek crossing, a distance of 10.6 miles. For the 36-hour period observed, the average flow at the upper station was 232.4 second-feet and at the lower station 220.0 second-feet, giving a total loss of 12.4 second-feet. This is equivalent to 1.17 second-feet per mile or 0.5 per cent of the total flow. Expressed in different terms, the loss per day per square foot of wetted area was 0.41 cubic foot.

The measurement of the North Poudre Canal was made from July 6 to 9, 1916, and covered a period of 58 hours. The section included extended from the rating station at the head of the canal to a station near Waverly, a distance of approximately 16 miles. During the observation there was a small inflow from Reservoir No. 15 and from a small spring a mile above the mouth of Camp-

bells Draw. Diversions included a small amount delivered to the Ripple ranch and a large head taken by the Scurvin Ditch. The average discharge at the head was 172 second-feet and the loss was 20.6 second-feet. This is at the rate of 1.29 second-feet per mile or 0.75 per cent of the total flow. The section measured includes a stretch of natural channel and for that reason the loss per square foot of wetted area can not be determined with any degree of accuracy.

Two measurements were secured on the Larimer and Weld Canal in 1917 while water was being carried for storage in the Windsor Reservoir. The section measured included a stretch 12 miles long with a 30-foot bottom between the head of the canal and Lake Lee. The first observation included a period of 12 days between March 29 and April 9 when the average discharge at the head of the canal was 63 second-feet. The loss during the period was 0.92 second-foot per mile or 1.5 per cent of the total flow which is equivalent to a loss of 0.81 cubic foot per day per square foot of wetted area. The second measurement included a period of 14 days between May 2 and 16 when the average discharge at the head was 242 second-feet. During this period this loss was 1.33 second-feet per mile or 0.5 per cent of the total flow which is equivalent to a loss of 0.64 cubic foot per day per square foot of wetted area.

When the investigation was undertaken it was believed that the difference between the duty at the head of canals and the duty at the head of representative laterals would give a fair approximation of the average loss in main canals and that the difference between the duty at the head of the lateral and at the farm would give the approximate loss in the laterals. On this assumption, if the averages shown in Table 14 are applicable to the entire valley, there was in main canals in 1916 a loss of 7 per cent and in 1917 a gain of 7 per cent. However, the data shown in the table are too meager to warrant the acceptance of these figures, but similar results are obtained by comparing the duty at the farm with the duty at the head of canals. In Tables 10 and 11 the total supply of water of the canals listed is shown to have been 395,000 acre-feet in 1916 and 414,000 acre-feet in 1917. By applying to the acreage of the various crops the figures representing duties, the majority of which are shown in Tables 9 to 14 and 18 to 27 it is possible to determine the total demand for each year under the canals listed. Duties for corn, peas, and other crops occupying less than 10 per cent of the acreage may be estimated without introducing a considerable error. The demand for 1916 determined in this manner was 354,000 acre-feet and to satisfy this demand there was a supply of 395,000 acre-feet, the

difference indicating a loss of 41,000 acre-feet, or approximately 10 per cent of the supply. In 1917 a demand of 435,000 acre-feet determined in a like manner was satisfied with a supply of 414,000 acre-feet, the difference indicating a gain of approximately 5 per cent. In view of the heavy rainfall of May, 1917, and the very large heads carried by all the canals in June and July of that year, it is believed that these approximations are in substantial accord with the facts. Conditions in 1916 were nearly normal and for that reason the assumption may be safely made that the average net loss in the canals between the head and the farm lateral is close to 10 per cent of the supply. This low figure is probably accounted for by the location of the canals one above another with the consequent inflow of seepage to counteract a part of the loss.

These figures indicate that absorption losses account for only a small part of the tare for losses charged by some of the common-carrier canals of the valley, and that most of it must go to make up inequalities of distribution. Under the present system each user receives at least his share after the tare has been deducted; but to take care of the inequalities of distribution and operation difficulties there is practically always a surplus in the canal which must go to some one to prevent its waste. It is possible that by spending a few thousand dollars for hire of extra riders and reducing the "beat" to a distance which will permit 2 or 3 visits every day to all gates and weirs to keep them clean and delivering the proper head, at least one day's run and perhaps two or three might be added each season to each reservoir right.

SEEPAGE SUPPLIES.

Practically the entire acreage irrigated in the valley is supplied to some extent with seepage water which has been collected in a reservoir or has returned to some channel, but the land dependent on seepage as its main supply is limited to the areas shown in Plate XIV.

FARM IRRIGATION.

While there are some exceptions, the trend of irrigation practice in the valley now is toward a frequent, rapid irrigation, which gives an even watering, minimizes percolation losses and end waste, permits the use of a large head with a consequent economy of time, and keeps the crops growing under moisture conditions with a minimum variation from the optimum.

Only two methods of irrigation are practiced. Alfalfa and grains are irrigated by flooding from field laterals. Sugar beets, potatoes,

and other row crops are irrigated by furrows between the rows. The method of flooding from field laterals, used on nearly two-thirds of the total irrigated area of the valley, does not vary essentially from the general practice. Supply ditches are located at the margin of the field; small laterals from these extend into the field; and through openings in these field laterals the water flows out over the land. In general, the effort is so to fit the layout of the supply ditches and field laterals to conditions of soil and topography that with a head

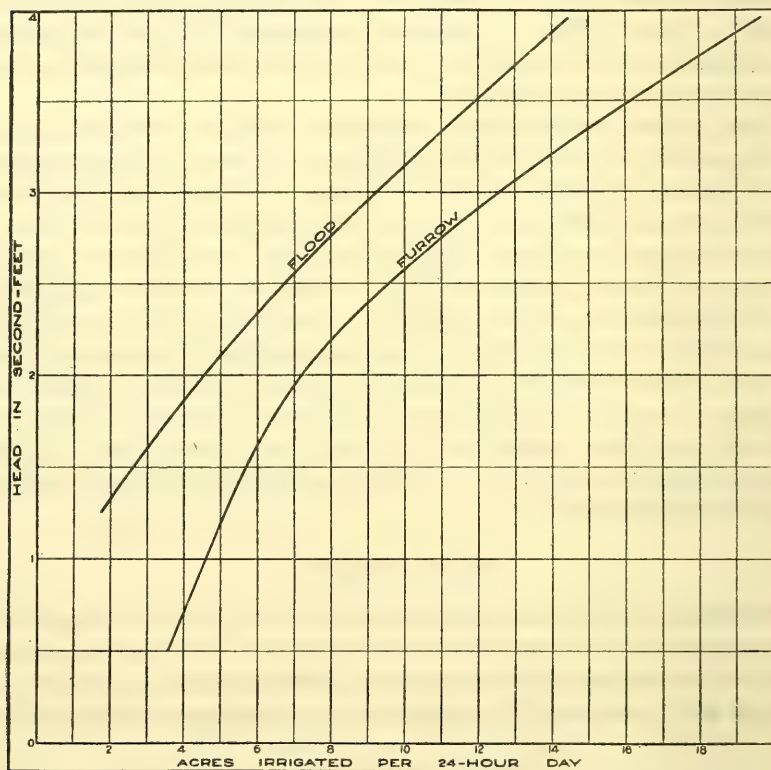


FIG. 4.—Relation between the head used and the area irrigated per 24-hour day for flood and furrow irrigation.

of from 2 to 3 second-feet a thorough irrigation may be secured with a minimum expenditure of time and work. For this reason the details of practice vary almost with the number of fields.

Supply ditches are carried along the margin of the field or follow ridges, the former location being preferred if conditions are at all suitable as less space is required and cultivating and harvesting may be carried on with less difficulty. Practically all these ditches are

equipped with concrete or wooden turnouts to supply the field laterals. For alfalfa the field laterals are permanent, but for annual crops they are made each spring with a ditching plow, and after irrigation is completed they are plowed flat again so that harvesting machinery

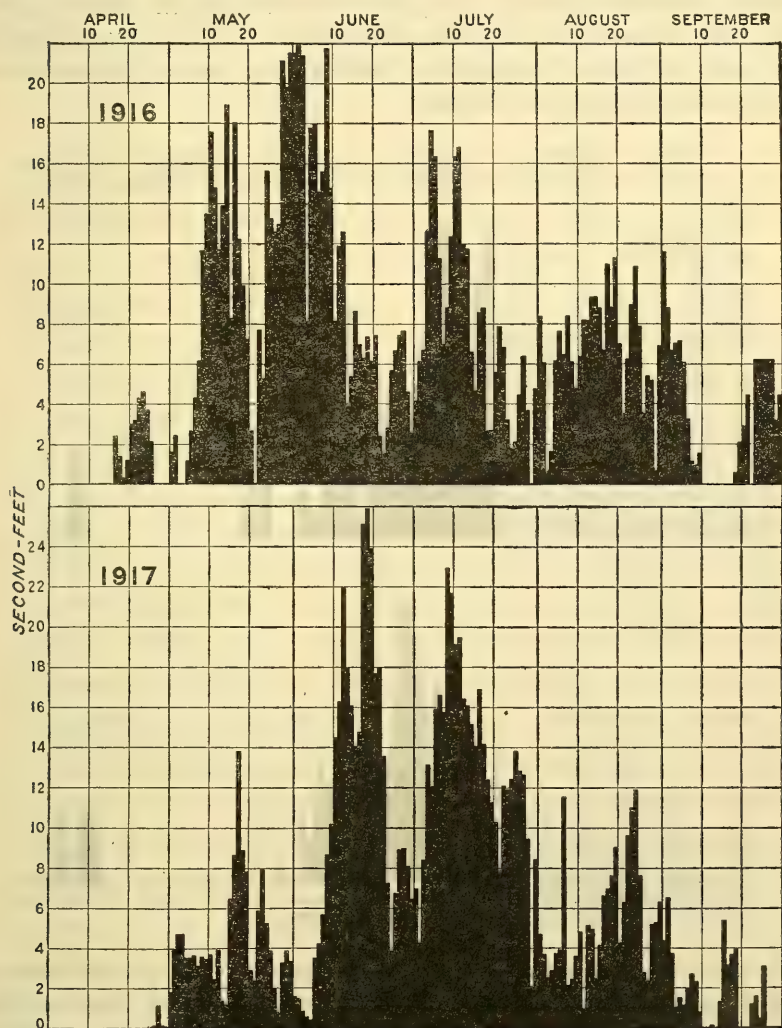


FIG. 5.—Irrigation of alfalfa. Water requirements of 988 acres in 1916 and of 686 acres in 1917.

may pass over them without difficulty. If the field to be irrigated is smooth and has a uniform slope, the field laterals are made parallel, 75 to 200 feet apart, and oblique to the main slope of the land. In this case the water from one lateral irrigates the field down to the

next. If the land is rolling, the laterals are spaced to follow the ridges and water is turned down both slopes. On very uneven land it is customary to build the field laterals to high points where the water is turned out to be directed here and there by temporary dikes thrown up with a shovel. To get the water from the lateral to the field cuts are made in the banks at intervals of from 5 to 20 feet and the water is forced through by checking the lateral farther down with a canvas, metal, or dirt dam.

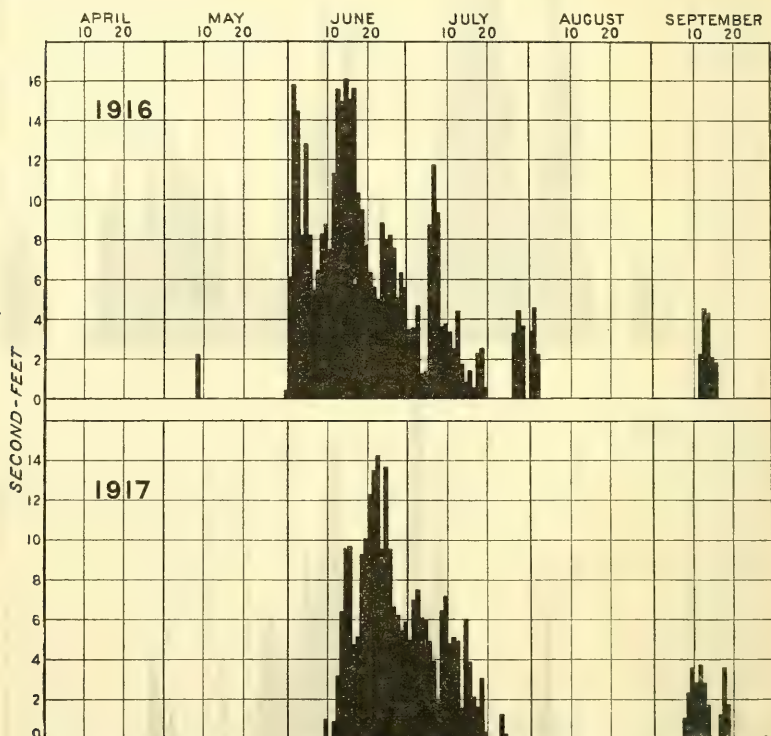


FIG. 6.—Irrigation of grain. Water requirements of 622 acres in 1916 and of 429 acres in 1917.

By far the greater part of the area irrigated by the furrow method is in sugar beets and potatoes, but corn, beans, peas, and truck are also irrigated in this manner. In the valley irrigation by this method consists in plowing furrows between the rows and running water down these furrows from notches cut in a ditch at the head of the field. Furrows are made in each middle with a shovel or other suitable plow and are especially deep for potatoes. To secure an even, fast irrigation, furrows are usually about 500 feet long, but the type of soil, slope of land, and amount of water available will cause a wide

variation in this particular. The general practice is to run water in each furrow, but some farmers use every other furrow and alternate for each irrigation the set used. Permanent head ditches are often fitted with concrete or wooden checks to hold the water up to the notches cut in the bank; otherwise canvas or metal dams are used. Where head ditches are necessary in the middle of a field they are

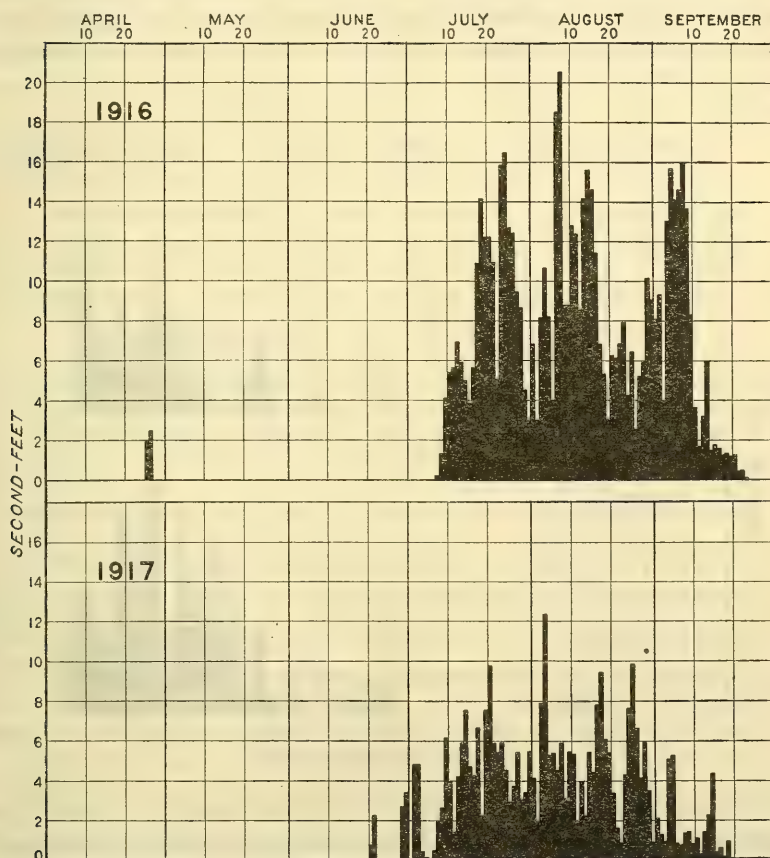


FIG. 7.—Irrigation of sugar beets. Water requirements of 584 acres in 1916 and 376 acres in 1917.

plowed out in the usual manner and dragged with a "V" to smooth and pack the sides. For turning the water from the head ditch to the furrows a notch may be made for each furrow or the water from a single cut may supply several furrows.

Under small canals with good water rights, when the farmer finishes his day of irrigating he goes to the head of his supply ditch and cuts off the water there for the night. But under large canals

conditions are different and when water is plentiful the safe operation of the canal requires that the user take his supply of water from the canal day and night until he orders it cut off by the ditch rider. When water is scarce the user takes it eagerly, day or night. It is necessity in these forms, rather than any virtue in its practice in the Cache la Poudre Valley, which is responsible for night irrigation there. Row crops are not often irrigated at night and matters are usually so arranged that the supply may be turned for the night on alfalfa or pasture land where a small excess of water will do no harm,

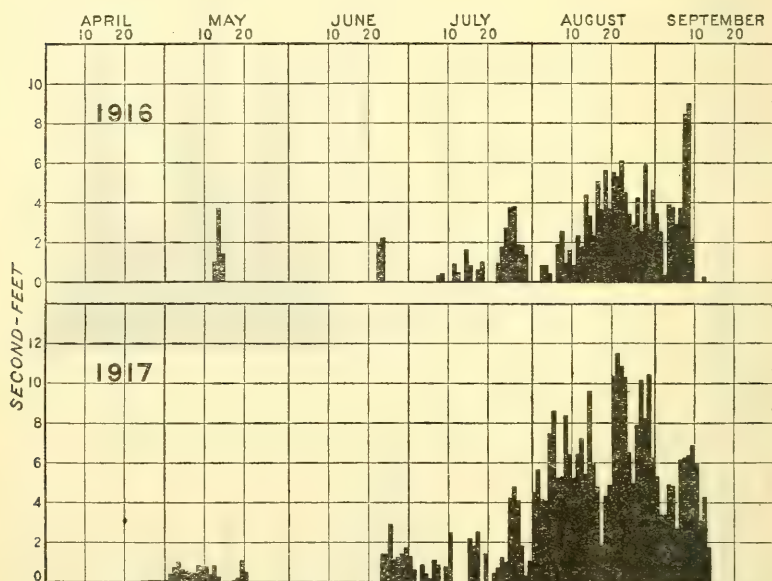


FIG. 8.—Irrigation of potatoes. Water requirements of 157 acres in 1916 and 285 acres in 1917.

It is seldom possible to apply enough water to a field for a uniform, thorough irrigation without having a certain run-off at the lower end. The amount of this run-off was determined for a number of fields of alfalfa and grain and was found to range from 2 to 18 per cent, with an average slightly under 6 per cent. In the majority of cases this can be called waste only with reference to the particular field from which it comes as the general practice is to collect it in ditches and use it on lower fields.

In figure 4 the relation between the head used and the area irrigated per 24-hour day is shown by curves for both flood and furrow irrigation. The curve for flood irrigation is based on 284 irrigations of fields of alfalfa and grain, while the curve for furrow irri-

gation is based on 324 irrigations of sugar beets, potatoes, and other row crops. The location and trend of the curve for furrow irrigation is influenced to a great extent by very rapid, alternate, furrow irrigation as practiced frequently on many of the farms of the valley.

In order to secure reliable data on farm irrigation a careful record was kept of the water used on about 25 farms during the period of the investigation. These farms were selected at widely scattered points and represent fairly the various conditions of soil, water rights, and irrigation practice encountered in the valley. In Table 15 each farm is listed with its location, general type of soil, and the kinds of water with which it is supplied.

TABLE 15.—*Farms selected for the investigation of farm irrigation.*

Farm.	Location.			Soil.	Water.
	Sec-tion.	Town-ship.	Range.		
R. D. Hughes.....	20	7	65	Fine sandy loam.....	Larimer & Weld Canal, Windsor Reservoir, Terry Lake; pumped from canal.
Wilson-Campbell.....	36	7	66	do.....	Larimer & Weld Canal, Windsor Reservoir, Terry Lake.
John A. Mair.....	10	7	68	do.....	Larimer & Weld Canal (No. 10 right).
C. A. Bartels.....	28	8	68	do.....	Larimer County Canal (stored in Clark Lake.)
C. A. Culver.....	28	8	68	do.....	Do.
Shafer-Haines.....	27	8	66	do.....	Pierce lateral of Larimer County Canal.
Shafer-Uhrick.....	27	8	66	do.....	Do.
Farmers' National Bank-Page.....	13	7	66	Loam and fine sandy loam.	Larimer County Canal.
Carpenter-McMurray..	30	6	63	Fine sandy loam.....	Greeley Canal, No. 2, Greeley-Poudre water.
Carpenter-Lyning.....	30	6	63	do.....	Do.
Charles F. Mason.....	20	6	65	Loam and fine sandy loam.	Greeley Canal, No. 2, Cache la Poudre Reservoir, Fossil Creek Reservoir.
Jackson-Alles.....	15	5	65	Fine sandy loam.....	Greeley Canal, No. 3.
C. A. Johnson.....	14	6	68	Loam and silty loam..	Fossil Creek Reservoir.
Charles and Henry Rassmussen.	6	5	64	Adobe and sandy loam	Ogilvy Ditch.
M. W. Dealy.....	21	8	69	Fine sandy loam.....	Jackson Ditch water stored in Dealy Reservoir through Larimer County Canal.
Jacob Ruff.....	22	8	69	do.....	Jackson Ditch water through Larimer County Canal.
H. R. Mitchell.....	34	8	69	Loam and sandy loam.	Little Cache la Poudre Ditch.
A. L. Bee.....	10	8	68	Sandy loam, loam, and silt loam.	North Poudre Canal; pumped well.
Frank Wells.....	17	7	67	Fine sandy loam.....	North Poudre Canal.
Frank J. Earle.....	34	8	68	Fine sandy loam and silt loam.	Boxelder Creek.
C. A. Duncan.....	36	7	68	Fine sandy loam.....	Lake Canal, Cache la Poudre Reservoir, Gray Reservoir.
John Stroh.....	34	7	68	Sandy loam.....	Boxelder Ditch.
Michie Bros.....	35	7	69	Gravelly loam.....	Pleasant Valley and Lake Canal, North Poudre Canal by exchange.
Fred Wells.....	24	7	69	Loam.....	Arthur Ditch.
Minor-Wilson.....	27	7	65	Loam and clay loam..	Pumped well.
Minor-Miller.....	27	7	65	do.....	Do.
Wilson-Bass.....	27	7	65	do.....	Do.

In Table 16 is given a general summary of all records of farm irrigation with the exception of those covering small areas of corn, peas, and other crops. The average head used may be taken as the head handled by one man, as only in a few cases were two men employed in irrigating a single field. The ratio of hours water was

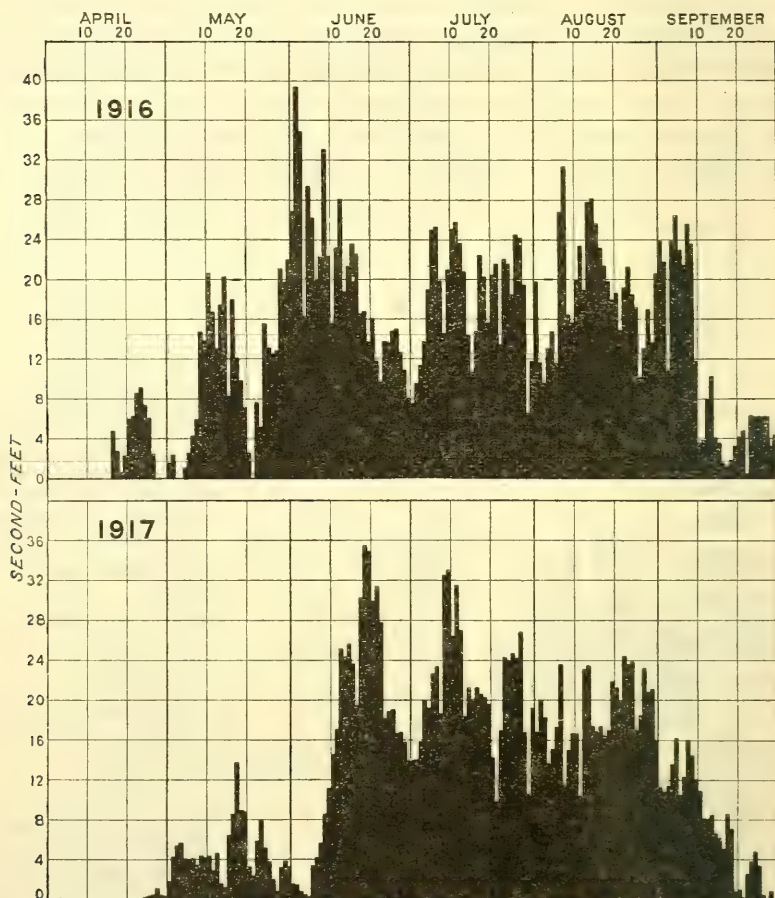


FIG. 9.—Water requirements of 2,500 acres of miscellaneous crops in 1916 and of 2,000 acres in 1917.

attended to hours it was run is lowered considerably by night irrigation, and with this eliminated the ratio would probably be from 80 to 90 for most of the crops. One of the farms for which duties were determined, the Jackson-Alles farm, is located on the delta between the Cache la Poudre and the South Platte, where the soil

is a nonretentive, very fine, sandy loam, underlain by coarse material which permits a very rapid drainage. This condition and the excellent water rights of the Greeley Canal No. 3 account for the very low duty of nearly 17 acre-feet per acre for potatoes on the farm. Charles F. Mason on his farm near Greeley frequently practices a very rapid light irrigation in alternate furrows and is enabled by this method to cover a very large acreage per day. In July, 1916, with a head of 3.75 second-feet a field of 8.1 acres of beans was irrigated in $4\frac{1}{2}$ hours, or at the rate of 43 acres per day. High duties are in most cases accounted for by good irrigation practice, but in a few cases the cost of pumping, a scarcity of water, or a high ground-water table is responsible.

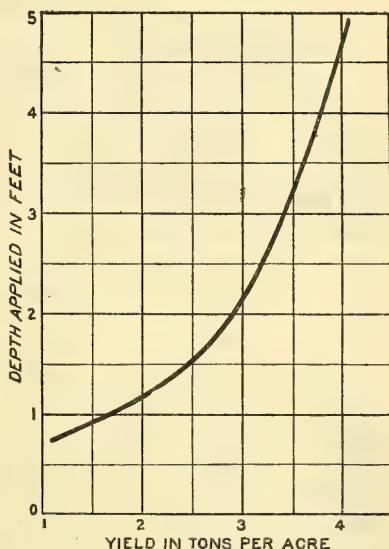


FIG. 10.—Irrigation of alfalfa. Relation between the depth of water applied and the yield.

Dates of irrigations varied widely with conditions, such as type of soil, depth to water table, rainfall, date of planting, water supply, and others. The greatest range noted was a difference of 90 days between the earliest and latest first irrigation of alfalfa, the dates being April 17 and July 16.

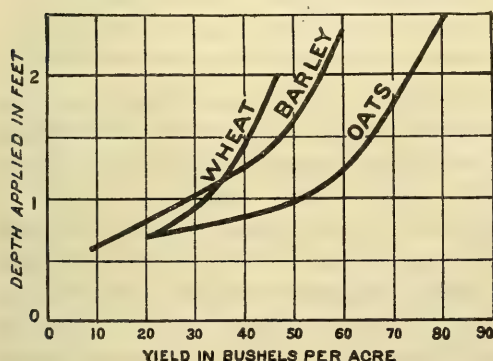


FIG. 11.—Irrigation of grain. Relation between the depth of water applied and the yield.

its proper number as a day of the year and then averaging these numbers

TABLE 16.—*Summary of records of the irrigation of crops in the Cache La Poudre Valley in 1916 and 1917.*

Crop.	Number of fields.	Total area of fields (acres).	Number of irrigations.			Size of head used (second-feet).			Ratio of hours attended to hours run.		
			Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
Alfalfa.....	74	1,674	3.02	7	1	2.59	7.78	0.58	0.57	1.00	0.04
Wheat.....	26	491	1.21	2	1	2.23	4.59	1.16	.56	.88	.22
Oats.....	15	196	1.64	4	1	2.25	5.20	1.21	.62	1.00	.33
Barley.....	31	364	1.27	3	1	2.10	5.22	.99	.62	1.00	.16
Sugar beets.	61	960	2.90	5	1	1.85	4.47	.52	.71	1.00	.46
Potatoes.....	38	442	3.79	6	2	1.99	3.70	.55	.68	1.00	.40
Beans.....	18	225	2.69	5	2	2.02	3.17	1.21	.80	1.00	.55

Crop.	Number of acres irrigated per day.			Depth of water applied (feet).			Average yield per acre.
	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.	
Alfalfa.....	6.02	19.52	1.55	2.57	13.59	0.52	2.75 tons.
Wheat.....	5.13	17.54	2.22	1.04	2.81	.17	27.75 bushels.
Oats.....	5.43	12.02	1.61	1.35	3.07	.60	48.06 bushels.
Barley.....	4.45	31.04	1.39	1.19	3.96	.14	40.73 bushels.
Sugar beets.	5.70	24.72	1.75	1.86	6.59	.32	12.56 tons.
Potatoes.....	6.78	22.27	1.51	2.20	16.94	.74	230.07 bushels.
Beans.....	15.63	54.80	6.72	.69	1.06	.34	22.75 bushels.

TABLE 17.—*Average dates of irrigation.*

Crop.	First.	Second.	Third.	Fourth.	Fifth.	Sixth.
Alfalfa.....	May 25	July 8	Aug. 3	Aug. 17	Aug. 8	.....
Grain.....	June 16	June 25	July 9	.....	.....	.....
Sugar beets.	July 19	Aug. 14	Aug. 31	Sept. 5	Sept. 2	.....
Potatoes.....	July 30	Aug. 15	Aug. 18	Aug. 21	Aug. 24	Sept. 8
Beans.....	June 24	July 27	July 24	Aug. 14	.....	.....

In figures 5 to 8 the distribution of the demand throughout the season is shown for the acreage in the principal crops on the farms selected for the investigation of farm irrigation. Figure 9 shows the combined demand of all the crops on these farms each year.

It will be noticed by reference to figure 1 that 5 inches, or more than one-third of the average annual rainfall, occurs in April and May. For this reason it usually happens that the crops have a natural start and are growing vigorously before any irrigation is necessary. When it becomes necessary to irrigate to bring up the crops, poor returns are expected.

The curves shown in figures 10, 11, 12, and 13 show for the four principal crops the relation between the depth of water applied and the yield obtained. The yield per acre for each field shown in Tables 17 and 18 was plotted against the corresponding depth of

water applied and the trend of the curves was governed by points determined by taking the arithmetical average of the coordinates

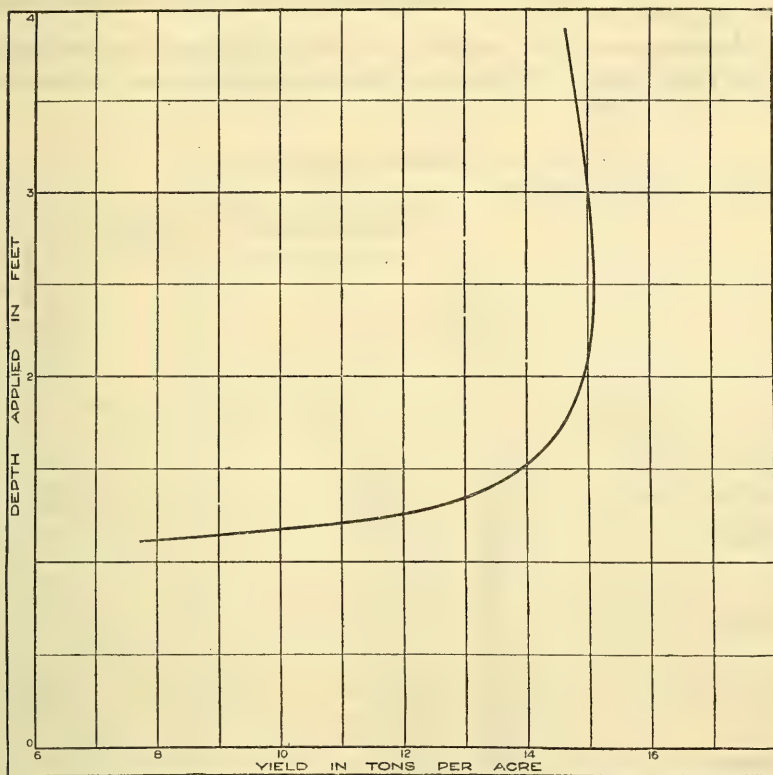


FIG. 12.—Irrigation of sugar beets. Relation between the depth of water applied and the yield.

of points within each half foot of depth. No satisfactory way was found to weight the points to take care of the difference in the area of the fields from which the unit value was determined, and for this reason the curves should be considered only as very close approximations of averages for the valley.

In Tables 9, 17 to 18, and 29 are given all the detailed records of farm irrigation for the two years of the investigation, with footings which summarize the data for each crop each year. The averages in the footings are true averages, involving

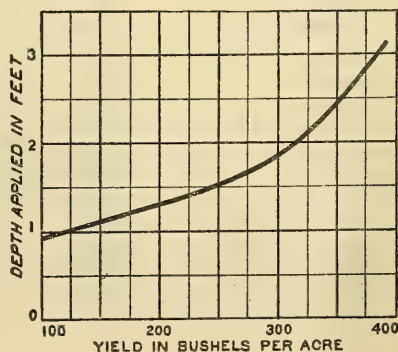


FIG. 13.—Irrigation of potatoes. Relation between the depth of water applied and the yield.

factors of time and area where necessary, and will be found to check by the following formula:

$$\frac{\text{Area} \times \text{number irrigations}}{\text{Acres irrigated per day}} \times \text{average flow} \times 1.98 = \text{depth applied} \times \text{area}.$$

Measurements were made by weirs and Cone-Venturi flumes on the farm supply ditches, and the results, therefore, include the losses on the farm.

TABLE 18.—*Irrigation of alfalfa in 1916.*

	Area of field (acres).	Number of irrigations.	Depth of water applied each irrigation (feet).						Total applied depth (feet).	Flow in second-feet.			Acres irrigated per day.	Ratio of hours attended to hours run.	Yield per acre (tons).
			First.	Second.	Third.	Fourth.	Fifth.	Sixth.		Max.	Min.	Ave.			
R. D. Hughes.....	5.94	2	1.32	0.42					2.74	1.99	1.09	1.61	7.97	0.81	1.40
Wilson & Campbell.....	42.82	2	0.57	0.12					0.69	3.51	1.68	2.44	14.04	0.58	1.40
	29.28	2	1.15	0.95					2.10	3.52	0.60	2.13	4.09	0.75	3.20
	28.81	3	0.75	0.61	0.15				1.51	3.25	0.67	1.83	7.29	0.67	4.10
John A. Mair.....	15.06	3	0.92	0.80	0.77				2.49	1.54	0.78	1.07	2.55	0.65	3.76
C. A. Bartels.....	22.94	1	0.62						0.62	4.18	4.18	4.18	13.41	0.61	3.07
	23.90	2	0.69	0.72					1.41	4.75	4.18	4.27	11.95	0.67	2.72
	8.35	2	1.14	0.52					1.66	3.74	2.17	3.04	7.29	0.71	2.72
	53.58	2	0.64	0.88					1.52	4.90	3.46	4.39	11.51	0.66	3.04
	27.54	2	0.96	0.18					1.14	3.30	1.82	2.80	9.71	0.68	2.53
C. A. Culver.....	11.58	3	0.84	0.69	0.42				1.95	4.12	1.36	3.38	10.37	0.16	2.14
	5.87	2	0.58	0.58					1.16	3.38	2.54	2.89	9.70	0.65	2.23
	8.78	2	0.57	0.28					0.85	4.05	1.73	3.69	17.21	0.98	1.68
	8.46	2	0.43	0.35					0.78	3.46	3.38	3.41	17.28	0.21	3.97
	11.62	3	0.82	0.11	0.49				1.42	4.05	1.36	3.22	13.51	0.63	3.21
	8.67	2	1.23	0.82					2.05	3.82	0.84	2.82	5.47	0.39	3.94
	19.74	3	1.15	0.53	0.04				1.72	3.90	1.67	3.07	10.65	0.34	1.52
	33.85	3	0.85	0.57	0.11				1.53	5.00	3.46	3.80	14.78	0.39	3.56
	7.46	2	1.00	0.36					1.36	4.12	3.46	3.74	10.85	0.58	3.96
Shafer-Haines.....	65.70	3	0.52	0.31	0.24				1.07	2.75	1.30	1.92	10.95	0.62	1.30
Farmers' National Bank—Page.....	11.72	1	1.43						1.43	2.82	0.82	1.65	2.30	0.49	2.20
	11.80	1	1.31						1.31	2.66	1.52	1.89	2.85	0.70	2.20
Carpenter-Lyning.....	9.18	3	1.51	0.70	0.66				2.87	3.10	0.10	1.62	3.36	0.69	1.20
	51.64	2	1.60	0.52					2.12	3.40	0.30	1.94	3.62	0.66	2.70
Chas. F. Mason.....	18.58	4	1.55	0.84	1.08	0.02			3.49	3.82	2.26	3.46	7.84	0.60	5.00
Jackson-Alles.....	28.40	3	6.24	1.17	1.31				8.72	6.00	0.25	2.29	1.57	0.42	3.60
C. A. Johnson.....	7.92	3	0.71	0.52	0.14				1.37	2.27	0.10	0.58	2.10	0.68	3.20
	14.31	3	0.71	0.34	0.83				1.88	2.27	0.07	1.28	4.06	0.67	2.50
Chas. and Henry Rassmussen.....	68.38	6	1.16	1.03	0.84	1.21	1.56	1.93	6.73	7.45	1.33	4.71	8.34	0.58	2.40
M. W. Dealy.....	30.60	4	0.86	0.78	0.59	0.95			3.18	9.20	1.34	5.44	13.56	0.80	3.82
Jacob Ruff.....	10.10	3	1.26	2.50	0.37				4.14	4.34	1.05	1.23	1.77	0.38	1.90
H. R. Mitchell.....	5.22	3	0.59	0.49	0.34				1.42	5.00	1.40	2.80	3.85	0.65	2.00
	5.48	3	0.65	0.36	0.32				1.33	5.00	1.40	1.90	8.81	0.74	2.00
A. L. Bee.....	33.00	1	0.54						0.54	2.30	0.90	1.40	3.70	0.35	3.70
	29.10	1	0.56						0.56	2.95	1.15	1.83	5.22	0.41	2.45
Frank Wells.....	33.00	2	1.28	0.09					1.37	5.55	0.38	1.71	4.92	0.65	3.24
Frank J. Earle.....	20.55	4	0.73	1.41	0.59	1.26			3.99	2.51	2.24	2.36	4.70	0.13	2.89
	16.30	4	1.54	0.30	1.24	0.40			3.48	2.53	2.24	2.40	5.40	0.18	2.07
C. A. Duncan.....	22.00	4	0.69	1.61	0.46	0.06			2.82	6.57	0.70	2.68	7.54	0.71	3.18
John Stroh.....	18.52	3	0.48	0.46	0.30				1.24	5.19	0.78	1.88	9.00	0.81	2.11
	12.02	4	0.48	0.41	0.19	0.60			1.68	3.95	0.16	1.32	6.27	0.74	2.12
Michie Bros.....	42.08	4	0.74	0.88	0.63	0.29			2.54	4.40	0.97	2.86	8.92	0.81	2.21
	8.25	2	1.22	0.38					1.60	3.46	2.08	2.42	6.00	0.65	2.15
	26.68	3	0.50	0.34	0.66				1.50	4.38	0.30	2.68	10.73	0.70	3.29
Total.....	988.08														
Average.....	22.45	2.77	1.00	0.65	0.55	0.73	1.56	0.93	2.23				2.53	6.26	0.57
Maximum.....	6								8.72	9.20			5.44	17.28	0.98
Minimum.....	1								0.54		0.07	0.58	1.57	0.13	1.20

TABLE 19.—*Irrigation of alfalfa in 1917.*

Farm.	Area of field (acres).	Number of irrigations.	Depth of water applied each irrigation (feet).							Total depth applied (feet).	Flow in second-feet.			Acres irrigated per 24-hour day.	Ratio of hours attended to hours run.	Yield per acre (tons).
			First.	Second.	Third.	Fourth.	Fifth.	Sixth.	Seventh.		Maximum.	Minimum.	Average.			
R. D. Hughes.....	43.00	2	0.60	0.40						1.00	3.55	2.30	2.69	10.61	1.00	2.50
Wilson-Campbell.....	27.90	3	.85	1.13	0.10					2.08	3.20	1.40	2.40	6.98	.66	3.63
	29.50	2	.96	1.08						2.04	4.40	2.40	3.40	6.51	.69	3.85
John A. Mair.....	17.18	5	.15	.24	.70	0.08	0.29			1.46	1.68	.50	1.09	7.42	.36	4.04
Shafer-Uhrick.....	43.50	3	.66	.79	.75					2.10	4.30	1.95	3.44	9.73	.64	1.80
Farmers' National Bank-Page.....	11.90	3	.97	1.20	.08					2.25	3.85	.95	2.74	6.03	.62	3.80
	5.21	2	.85	.75						1.60	2.25	.88	1.88	4.72	.66	2.80
Carpenter-Lyning.....	9.20	3	2.00	1.63	.02					3.65	2.67	.25	1.67	2.06	.68	2.07
	48.30	5	1.32	1.96	.05	.22	.02			3.57	5.53	.20	1.73	4.82	.60	2.70
Chas. F. Mason.....	18.00	4	1.08	1.16	.82	1.05				4.11	3.56	1.13	2.73	5.30	.67	5.60
Jackson-Alles.....	25.00	7	4.58	.38	2.15	2.92	.42	2.62	0.52	13.59	6.16	.67	3.43	3.50	.58	2.40
	22.30	3	3.18	2.10	1.81					7.09	5.21	1.22	3.53	2.97	.66	2.40
C. A. Johnson.....	14.52	2	1.49	.91						2.40	2.80	.57	1.58	2.61	.56	3.35
	5.11	2	2.60	.90						3.56	5.12	.00	1.38	1.55	.44	2.84
C. & H. Rassmussen.....	64.60	5	1.04	.89	1.03	.92	1.06			4.94	6.70	2.80	4.70	9.65	.58	2.40
M. W. Dealy.....	30.60	4	1.06	.88	.84	.64				3.42	11.32	.63	7.78	19.52	.85	4.40
Jacob Ruff.....	10.10	2	2.13	1.68						3.82	2.94	1.50	1.95	2.03	.50	2.97
A. L. Bee.....	40.00	2	.63	.50						1.13	3.46	.77	1.82	6.34	.65	3.35
	15.00	3	1.03	.55	.49					2.07	3.41	.25	1.89	5.44	.69	2.10
Frank Wells.....	32.18	3	.92	1.56	1.76					4.24	4.18	.14	1.55	2.18	.47	3.78
Frank J. Earle.....	20.55	3	.30	.36	.38					1.04	3.30	1.27	1.65	9.42	.19	3.49
	16.22	3	.45	.67	.14					1.26	1.90	1.24	1.53	7.25	.04	2.26
C. A. Duncan.....	11.03	5	1.11	.96	.33	.24	.17			2.81	2.98	.45	1.83	6.43	.34	1.92
John Stroh.....	12.02	2	.39	.52						.91	4.06	.57	2.61	11.31	.39	1.87
	17.05	4	.14	.34	.11	.22				.81	3.28	.73	1.93	19.03	.46	0.96
Michie Bros.....	36.26	3	.86	.83	1.04					2.73	6.62	1.51	3.82	8.31	.60	2.60
	32.58	2	.42	.74	.42					1.58	6.62	.37	3.60	13.46	.62	2.84
	8.25	3	.49	1.01	.92					2.42	5.10	1.51	4.02	9.86	.55	2.85
Fred Wells.....	1.61	1	.87							.87	.90	.72	.75	1.64	.55	5.15
Wilson Bros.....	16.80	1	.52							.52	2.40	1.88	2.29	8.76	.91	2.10
Total.....	685.57															
Average.....	22.85	3.37	1.07	.94	0.76	.82	.52	2.62	.52	3.07			2.65	5.78	.57	2.84
Maximum.....	7									13.59	11.32		7.78	19.52	1.00	5.60
Minimum.....	1									.52		.00	.75	1.55	.40	.96

TABLE 20.—*Irrigation of wheat in 1916 and 1917.*

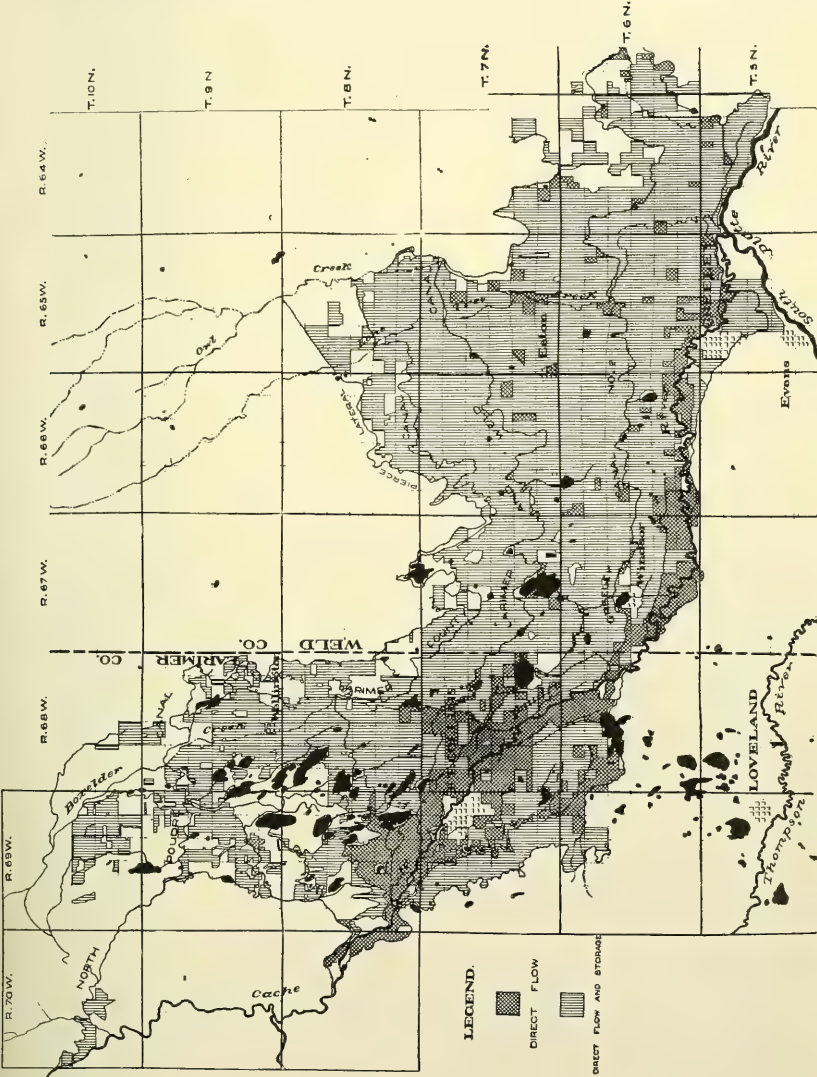
Field.	Area of field (acres).	Number of irrigations.	Depth for each irrigation (feet).		Total depth applied (feet).	Flow in second-feet.			Acres irrigated per 24-hour day.	Ratio of hours attended to hours run.	Yield per acre (bushels)
			First.	Second.		Maximum.	Minimum.	Average.			
1916.											
C. A. Bartels.....	40.79	1	0.80	.....	0.80	5.10	3.38	4.59	11.39	0.84	43.50
C. A. Culver.....	29.88	1	1.79	.....	1.79	3.63	1.58	3.16	3.49	.48	13.70
Farmers' National Bank-Page.....	7.68	2	1.02	1.30	2.32	2.02	1.38	1.75	2.99	.52	26.20
	8.22	2	.74	.81	1.55	2.32	1.55	1.80	4.61	.58	23.80
Carpenter-Lyning.....	13.00	2	1.22	.87	2.09	2.96	1.02	1.16	2.27	.74	9.40
C. A. Johnson.....	15.12	2	.64	.31	.95	2.44	.14	1.32	5.54	.69	13.70
M. W. Dealy.....	58.60	1	.60	.....	.60	4.63	2.60	3.25	10.82	.81	26.40
H. R. Mitchell.....	42.00	1	.44	.....	.44	4.75	2.16	3.75	17.10	.85	27.00
A. L. Bee.....	20.30	1	.72	.....	.72	2.40	.90	1.42	3.04	.43	27.20
	10.55	1	.77	.....	.77	2.05	.90	1.38	2.58	.39	33.20
Frank Wells.....	3.00	1	.60	.....	.60	1.44	1.30	1.40	4.50	.62	33.30
Frank J. Earle.....	9.59	1	.74	.....	.74	2.53	2.53	2.53	6.77	.22	33.40
	14.05	2	.48	.41	.89	2.91	2.53	2.69	12.05	.34	31.00

TABLE 20.—*Irrigation of wheat in 1916 and 1917—Continued.*

Field.	Area of field (acres).	Number of irrigations.	Depth for each irrigation (feet).		Total depth applied (feet).	Flow in second-feet.			Acres irrigated per 24-hour day.	Ratio of hours attended to hours run.	Yield per acre (bush-els).
			First.	Second.		Maximum.	Minimum.	Average.			
1916.											
C. A. Duncan.....	20.39	2	2.18	.63	2.81	6.50	.30	2.27	3.20	.30	33.00
Michie Brothers.....	15.36	1	.17		.17	3.03	.62	1.54	17.54	.71	51.30
	7.39	1	1.30		1.30	4.32	.08	1.96	3.00	.54	50.30
Total.....	315.92										
Average.....	19.74	1.27	.87	.65	1.03			2.13	5.20	.55	25.39
Maximum.....		2			2.81	4.75		4.59	17.54	.85	51.30
Minimum.....		1			.17		.08	1.16	2.27	.22	9.40
1917.											
Shafer-Uhrick.....	11.93	1	1.00		1.00	2.16	2.16	2.16	4.28	.31	34.00
C. A. Johnson.....	15.90	2	.33	.56	.89	3.40	.40	1.60	10.74	.40	?
M. W. Dealy.....	58.60	1	.82		.82	7.34	1.75	3.71	8.99	.88	22.00
A. L. Bee.....	30.00	1	.98		.98	2.42	1.09	1.79	3.62	.63	33.30
Frank Wells.....	5.00	1	1.07		1.07	3.92	.18	1.21	2.22	.57	40.00
Frank J. Earle.....	11.61	1	1.03		1.03	3.60	1.65	2.72	5.26	.57	43.60
	9.56	1	.84		.84	1.76	1.08	1.39	3.28	.50	29.30
	4.60	1	1.63		1.63	2.16	1.89	2.06	2.51	.45	37.00
C. A. Duncan.....	12.45	1	2.71		2.71	3.53	1.95	3.18	2.32	.54	42.40
Michie Brothers.....	15.36	1	.83		.83	5.10	3.78	4.01	9.57	.75	46.70
Total.....	175.01										
Average.....	17.50	1.09	.99	.56	1.04			2.41	4.99	.59	32.03
Maximum.....		2			2.71	7.34		4.01	10.74	.88	46.70
Minimum.....		1			.82		.18	1.21	2.22	.31	22.00

TABLE 21.—*Irrigation of oats in 1916 and 1917.*

Farm.	Area of field (acres).	Number of irrigations.	Depth applied each irrigation (feet).				Total depth applied, feet.	Flow in second-feet.			Acres irrigation per 24-hour day.	Ratio of hours attended to hours run.	Yield per acre (bushels).
			First.	Second.	Third.	Fourth.		Maximum.	Minimum.	Average.			
1916.													
Wilson-Campbell.....	17.10	2	1.21	0.13.	.....	.....	1.33	3.25	1.22	2.50	7.43	0.64	70.00
C. A. Bartels.....	9.51	1	1.80	.....	.....	.....	1.80	4.19	4.19	4.19	10.37	.64	20.80
C. A. Culver.....	10.56	1	1.41	.....	.....	.....	1.41	5.00	1.58	2.83	3.98	.81	72.90
Charles F. Mason.....	16.10	4	1.45	.81	0.88	0.92	3.07	3.94	3.00	3.45	8.92	.86	65.20
A. L. Bee.....	12.50	1	1.39	.....	.....	.....	1.39	2.95	0.55	1.73	1.61	.39	53.30
Frank Wells.....	6.76	1	.60	.....	.....	.....	.60	1.44	1.30	1.40	4.63	.60	42.90
Total.....	81.24												
Average.....	11.61	1.81	.98	.46	.88	.92	1.51			2.35	5.55	.64	52.50
Maximum.....		4					3.07	5.00		4.19	10.36	.86	72.90
Minimum.....		1					.60		.55	1.40	1.61	.39	20.80
1917.													
Wilson-Campbell.....	10.10	2	1.15	.86	.....	.....	2.01	4.70	1.50	2.80	5.61	.88	61.00
Shafer-Uhrick.....	33.30	1	.70	.....	.....	.....	.70	3.19	1.00	2.04	5.79	.65	23.20
A. L. Bee.....	12.50	1	.60	.....	.....	.....	.60	2.00	1.39	1.90	6.25	.67	28.00
Farmers' National Bank-Page.....	14.60	2	.60	.50	.....	.....	1.10	3.90	.95	2.00	7.22	.59	29.70
Charles F. Mason.....	8.90	2	1.26	1.18	.....	.....	2.44	3.56	1.10	2.99	5.77	.47	77.80
Frank Wells.....	8.54	1	1.07	.....	.....	.....	1.07	3.29	.18	1.21	2.23	.58	76.50
C. A. Duncan.....	11.60	2	1.28	1.09	.....	.....	2.37	2.70	1.60	2.02	3.37	.33	62.60
Michie Brothers.....	5.20	2	1.19	.48	.....	.....	1.67	6.34	3.10	5.20	12.02	.82	70.40
Minor-Miller.....	9.61	2	.45	.21	.....	.....	.66	2.40	.52	1.30	7.90	1.00	56.70
Total.....	114.34												
Average.....	12.71	1.52	.85	.73			1.23			2.16	5.32	.61	44.90
Maximum.....		2					2.44	6.34		5.20	12.02	1.00	77.80
Minimum.....		1					.60		.18	1.21	2.23	.33	23.20



COMPARISON OF THE AREA IRRIGATED BY DIRECT FLOW AND THE AREA IRRIGATED BY DIRECT FLOW AND STORED WATER.

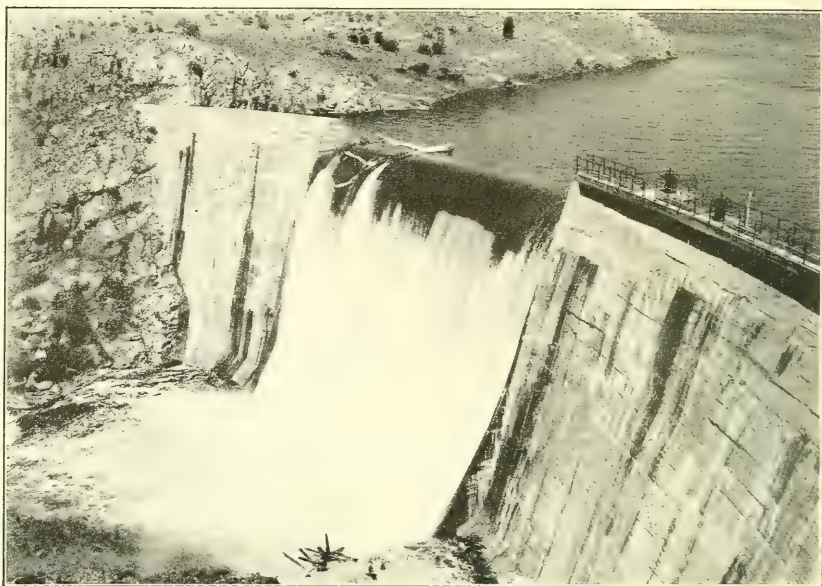


FIG. 1.—HALLIGAN DAM OF THE NORTH POUDE SYSTEM. DEPTH OF $1\frac{1}{2}$ FEET ON THE SPILLWAY.



FIG. 2.—EFFECT OF WAVE ACTION ON THE INNER SLOPE OF THE DAM OF NORTH POUDE RESERVOIR No. 15.

TABLE 22.—Irrigation of barley in 1916 and 1917.

Farm.	Area of field (acres).	Number of irrigations.	Depth each irrigation (feet).			Total depth applied (feet).	Flow in second-feet.			Acres irrigated per 24-hour day.	Ratio of hours attended to hours run.	Yield per acre (bushels).
			First.	Second.	Third.		Maximum.	Minimum.	Average.			
1916.												
R. D. Hughes.....	35.20	1	0.36			0.36	2.92	1.81	2.41	13.25	0.89	39.80
John A. Mair.....	17.46	1	1.18			1.18	2.09	1.26	1.86	3.13	.89	38.10
C. A. Culver.....	10.73	1	.70			.70	2.95	2.95	2.95	8.32	.68	36.80
Shafer-Haines.....	13.85	1	.54			.54	2.75	2.75	2.75	10.07	.73	6.40
Farmers' National Bank-Page.....	14.63	2	.96	1.28		2.24	2.32	1.38	1.92	3.39	.57	18.50
Carpenter-Lyning.....	16.60	2	1.50	.83		2.33	3.56	1.02	1.50	2.52	.71	14.30
Jackson-Alles.....	9.40	2	1.68	2.28		3.96	3.60	2.65	3.39	3.39	.65	54.50
C. A. Johnson.....	7.43	1	1.82			1.82	3.80	.87	2.20	2.92	.74	17.20
A. L. Bee.....	19.40	1	.14			.14	3.25	2.25	2.30	31.04	.27	13.30
Frank Wells.....	10.34	1	1.04			1.04	1.64	1.30	1.48	2.82	.63	15.00
Frank J. Earle.....	21.00	1	1.11			1.11	2.91	2.53	2.62	4.67	.41	59.50
	9.56	1	1.33			1.33	2.31	2.16	2.20	3.27	.30	33.50
	3.14	1	1.30			1.30	2.91	2.91	2.91	4.43	.71	47.80
Michie Brothers.....	9.36	1	1.43			1.43	3.43	2.95	3.24	4.49	.74	41.45
Minor-Wilson.....	25.50	1	.78			.78	2.13	1.85	2.02	5.14	.70	66.00
Total.....	224.45											
Average.....	14.02	1.18	.91	1.33		1.15			2.16	4.39	.66	35.47
Maximum.....		2				3.96	3.80		3.39	31.04	.89	66.00
Minimum.....		1				.14		.87	1.48	2.52	.27	6.40
1917.												
John A. Mair.....	9.28	1	.68			.68	1.44	1.35	1.42	4.12	.93	62.20
Shafer-Uhrick.....	5.43	1	1.00			1.00	.99	.99	.99	1.95	.31	5.50
Carpenter-Lyning.....	5.83	1	.97			.97	1.60	1.60	1.60	5.83	.50	40.00
C. A. Johnson.....	12.64	1	1.25			1.25	4.00	1.10	2.33	3.70	.16	
Farmers' National Bank-Page.....	7.81	2	2.10	1.01		3.11	3.40	.73	1.96	2.50	.51	39.70
	3.03	2	.86	.77		1.65	1.35	.53	1.13	2.74	.66	33.30
	7.68	2	1.40	.80		2.20	4.10	1.07	3.12	5.50	.75	18.20
A. L. Bee.....	5.00	1	1.98			1.98	1.90	1.09	1.40	1.39	.37	46.00
Frank Wells.....	15.30	1	.85			.85	2.47	.72	1.73	4.04	.75	63.00
Frank J. Earle.....	21.00	1	1.15			1.15	3.30	1.44	2.27	3.91	.39	60.00
	9.49	2	.54	.46		1.00	1.92	1.22	1.35	5.33	.53	56.90
Michie Brothers.....	7.39	1	.87			.87	4.02	3.78	3.97	9.10	.41	46.30
	9.36	1	1.08			1.08	4.02	3.48	3.94	7.24	.64	46.40
	5.90	2	.17	1.25		1.42	5.53	3.94	5.22	14.52	.87	46.40
Minor-Miller.....	4.51	2	.47	.29		.76	1.36	.75	1.14	6.00	1.00	61.40
Wilson-Bass.....	10.40	3	.19	.19	.62	1.00	2.07	1.94	2.06	11.99	.81	62.80
Total.....	140.05											
Average.....	8.75	1.42	.98	.64	.62	1.25			2.00	4.52	.55	49.16
Maximum.....		3				3.11	5.53		5.22	14.52	1.00	63.00
Minimum.....		1				.68		.53	.99	1.39	.16	5.50

TABLE 23.—Irrigation of sugar beets in 1916.

Farm.	Area of field (acres).	No. of irrigations.	Water applied each irrigation (feet).					Total depth applied (feet).	Flow in second-feet.			Acres irrigated per 24-hour day.	Ratio of hours attended to hours run.	Yield per acre (tons).
			First.	Second.	Third.	Fourth.	Fifth.		Maximum.	Minimum.	Average.			
R. D. Hughes.....	13.50	3	0.90	0.60	0.17	.....	.....	1.64	2.80	1.34	2.12	7.57	0.89	12.40
Wilson-Campbell.....	17.10	3	.39	.30	.61	.....	.....	1.30	4.05	.75	2.65	12.13	1.00	10.30
John A. Mair.....	32.54	3	.67	.55	.08	.....	.....	1.30	1.59	.54	1.01	4.65	.77	10.97
.....	7.65	3	.90	.86	1.12	.....	.....	2.88	1.44	.68	1.20	2.47	.76	10.85
C. A. Bartels.....	24.68	3	1.46	.87	1.49	.....	.....	3.82	4.97	4.10	4.47	6.97	.68	17.11
.....	33.60	3	.78	1.17	.78	.....	.....	2.73	5.15	1.00	4.09	8.90	.89	15.81

TABLE 23.—Irrigation of sugar beets in 1916—Continued.

Farm.	Area of field (acres).	No. of irrigations.	Water applied each irrigation (feet).					Total depth applied (feet).	Flow in second-feet.			Acres irrigated per 24-hour day.	Ratio of hours attended to hours run.	Yield per acre (tons).
			First.	Second.	Third.	Fourth.	Fifth.		Maximum.	Minimum.	Average.			
C. A. Culver.....	31.74	2	1.07	.98	.....	.....	.....	2.05	4.05	1.32	3.77	7.14	.71	9.85
	36.29	2	.79	.64	.....	.....	.....	1.43	4.75	3.28	4.21	11.69	.82	9.85
	2.30	2	.53	.90	.....	.....	.....	1.43	3.68	2.65	2.95	4.08	1.00	9.85
	6.12	2	.58	.52	.....	.....	.....	1.10	3.97	2.65	3.60	6.53	.67	9.85
	2.06	1	.32	.....	.....	.....	.....	.32	3.97	3.97	3.97	24.72	1.00	9.85
Shafer-Haines.....	20.80	4	.46	.84	.33	.45	.....	2.07	2.45	1.07	1.12	5.20	.60	8.40
Carpenter-Lyning.....	21.10	2	.57	.66	.....	.....	.....	1.23	4.75	.08	.86	2.80	.69	7.50
	11.90	2	.78	.56	.82	.....	.....	2.16	4.75	.08	.66	1.84	.66	7.50
Charles F. Mason.....	9.00	4	.45	.73	1.14	.49	.....	2.81	5.89	1.63	3.48	9.76	.64	15.00
	17.20	4	.24	.41	.48	.75	.....	1.88	5.62	1.57	3.48	14.74	.66	15.90
Jackson-Alles.....	9.26	4	.80	2.06	.49	1.62	.....	4.96	5.50	1.85	3.04	4.85	.56	13.80
C. A. Johnson.....	12.92	2	.26	.29	.16	.....	.....	.71	1.06	.13	.52	4.27	.69	9.00
Charles and Henry Rassmussen.....	29.60	4	.51	.57	.22	.28	.....	1.58	4.10	1.42	2.30	11.66	.89	15.70
	9.90	2	.83	.49	.83	.....	.....	2.15	3.49	1.50	1.90	5.14	.84	11.10
	11.80	2	.29	.44	.....	.....	.....	1.73	1.85	.90	1.33	3.05	.79	6.20
H. R. Mitchell.....	47.50	2	.57	.26	.....	.....	.....	.83	5.50	1.40	3.10	7.89	.69	13.70
A. L. Bee.....	19.60	2	.60	.48	.....	.....	.....	1.08	2.50	.70	.98	3.57	.75	14.78
Frank Wells.....	13.54	2	.27	.37	.....	.....	.....	.64	2.59	.40	1.13	6.99	.84	12.67
Frank J. Earle.....	11.61	2	1.00	.96	.61	.....	.....	2.57	2.38	2.24	2.31	5.36	.55	13.20
	11.24	2	.71	.57	.41	.....	.....	1.69	2.45	2.24	2.34	8.26	.85	13.00
	4.02	2	.55	.00	.57	.....	.....	1.72	2.45	2.24	2.33	8.04	.78	10.70
C. A. Duncan.....	22.40	2	.38	1.30	.....	.....	.....	3.68	6.40	.20	1.63	1.75	.65	9.94
John Stroh.....	5.88	2	.51	1.25	1.90	.....	.....	4.66	7.37	1.00	4.42	5.64	.55	11.24
	5.41	2	.71	2.88	.....	.....	.....	3.59	6.22	.26	3.55	3.93	.61	11.24
	34.74	2	.94	1.25	1.21	.....	.....	3.40	6.22	.36	3.58	6.25	.70	11.24
Michie Brothers.....	6.69	2	.39	.64	.50	.54	.80	2.87	3.36	1.96	2.73	9.45	.88	17.10
	5.88	2	.17	.42	.69	.....	.....	1.28	2.45	1.96	2.32	10.86	.69	17.10
Minor-Wilson.....	10.40	2	.80	.59	.81	.....	.....	2.20	2.33	1.88	2.06	5.55	.96	13.00
	14.10	1	.70	.....	.....	.....	.....	.70	2.26	1.94	2.09	5.94	.80	13.90
	7.30	3	.62	.56	.73	.....	.....	1.91	2.96	1.57	2.07	6.42	.99	13.80
Total.....	584.32	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average.....	15.79	2.74	.78	.74	.67	.58	.80	1.86	.....	.....	1.91	5.58	.73	12.15
Maximum.....	.....	5	.....	.....	.....	.....	.....	4.96	7.37	.....	4.47	24.72	1.00	17.10
Minimum.....	.....	1	.....	.....	.....	.....	.....	.32	.....	.08	.52	1.75	.55	6.20

TABLE 24.—Irrigation of sugar beets in 1917.

Farm.	Area of field (acres). ^a	Number of irrigations.	Depth of water applied each irrigation (feet).					Flow in second-feet.			Acres irrigated per 24-hour day.	Ratio of hours attended to hours run.	Yield per acre (tons).	
			First.	Second.	Third.	Fourth.	Fifth.	Total depth applied (feet).	Maximum.	Minimum.				Average.
R. D. Hughes.....	16.20	2	0.98	0.43	...	...	...	1.41	2.70	1.50	1.97	5.40	0.99	11.05
Wilson-Campbell.....	21.50	3	.59	.76	1.05	...	...	2.40	4.20	2.00	2.90	7.51	.64	18.92
John Mair.....	31.38	2	.21	.81	...	...	...	1.02	1.40	.04	.87	3.36	.57	11.73
	13.12	4	.37	.28	.07	.45	...	1.17	1.40	.35	.84	5.75	.78	11.73
Shafer-Uhrick.....	10.37	3	.59	.14	.36	...	...	1.09	1.90	1.54	1.64	9.00	.60	4.82
Carpenter-Lyning.....	12.60	4	1.50	.99	.78	1.76	...	5.03	5.18	.31	1.68	2.50	.65	14.80
Chas. F. Mason.....	15.75	5	.30	.21	.18	.19	.45	1.33	3.25	1.82	2.69	20.11	.89	17.20
Jackson-Alles.....	22.50	4	1.00	.15	.64	.30	...	2.09	5.15	1.65	4.29	16.18	.64	14.80
	10.30	5	.54	1.37	1.77	1.56	1.31	6.59	4.06	.74	2.62	3.92	.61	15.00
Chas. and Henry Rassmussen.....	29.60	5	.02	.43	.31	.35	.40	1.51	3.00	.50	1.68	11.01	.71	15.83
	11.80	3	.14	.82	.11	...	...	1.07	2.20	.20	.76	4.23	.76	15.83
C. A. Johnson.....	7.91	2	.28	.46	...	...	...	.74	2.15	.50	.89	4.72	.74	8.15
A. L. Bee.....	20.00	2	.59	.84	...	...	...	1.43	3.04	.77	1.45	4.03	.67	14.20
Frank J. Earle.....	9.48	2	.94	.41	...	...	...	1.35	1.82	1.19	1.31	3.86	.85	12.34
	4.02	3	.56	.32	.27	...	...	1.15	2.55	1.19	1.68	7.52	.91	8.95
	9.59	3	.28	.74	.24	...	...	1.26	2.72	1.28	1.86	9.10	.89	10.00
C. A. Duncan.....	30.86	3	.69	.77	.61	...	...	2.07	3.20	.70	1.81	5.17	.46	12.62
John Stroh.....	3.71	2	.57	.81	...	...	...	1.38	4.14	1.54	3.01	8.69	1.00	10.85
	40.15	3	.41	1.21	.16	...	...	1.78	4.05	.20	1.95	6.55	.82	10.85

TABLE 24.—*Irrigation of sugar beets in 1917—Continued.*

Farm.	Area of field (acres).	Number of irrigations.	Depth of water applied each irrigation (feet).					Total depth applied (feet).	Flow in second-feet.			Acres irrigated per 24-hour day.	Ratio of hours attended to hours run.	Yield per acre (tons).
			First.	Second.	Third.	Fourth.	Fifth.		Maximum.	Minimum.	Average.			
Michie Brothers.....	6.69	3	.73	.76	.61	.....	.....	2.10	4.26	2.13	3.36	9.49	.97	12.41
Fred Wells.....	5.88	4	.95	.51	.54	.60	.....	2.60	5.89	3.25	4.25	12.94	.92	14.59
Minor-Miller.....	12.25	2	.55	.38	.....	.....	.....	.93	1.10	.15	.68	2.89	.62	15.42
Wilson-Bass.....	14.70	3	.48	.83	.57	.....	.....	1.88	2.53	1.81	2.08	6.78	.56	14.80
.....	6.52	2	.34	.46	.....	.....	.....	.80	2.40	1.40	1.61	8.02	.51	9.96
.....	8.81	3	1.50	1.29	.90	.....	.....	3.69	2.40	1.02	1.55	2.49	.58	9.96
Total.....	375.69	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average.....	15.03	3.15	.55	.95	.47	.62	.58	1.87	.....	.....	1.75	5.87	.68	13.21
Maximum.....	.....	.....	.....	.....	.....	.....	.....	6.59	5.89	.....	4.28	20.11	1.00	18.92
Minimum.....	.....	.....	.....	.....	.....	.....	.....	.74	.....	.04	.68	2.49	.46	4.82

TABLE 25.—*Irrigation of potatoes in 1916.*

Farm.	Area of field (acres).	Number of irrigations.	Depth of water applied each irrigation (feet).						Total depth applied (feet).	Flow in second-feet.			Acres irrigated per 24-hour day.	Ratio hours attended to hours run.	Yield per acre (bushels).
			First.	Second.	Third.	Fourth.	Fifth.	Sixth.		Maximum.	Minimum.	Average.			
R. D. Hughes.....	16.20	3	0.50	0.42	0.41	.....	.....	.....	1.43	2.82	1.31	1.84	8.22	0.78	270.00
.....	11.60	2	.36	.40	.....	.....	.....	.....	.74	2.80	2.74	2.76	4.46	.86	344.00
Wilson-Campbell.....	5.75	4	.42	.26	.14	0.63	.....	.....	1.45	2.70	1.18	1.88	10.32	.68	204.00
.....	34.50	5	.20	.41	.17	.71	0.52	.....	2.02	4.22	.68	2.72	13.38	.58	264.00
.....	4.72	3	.48	.15	.88	.....	.....	.....	1.51	2.96	1.18	1.72	6.80	.60	48.00
Shafer-Haines.....	9.48	4	.31	.32	.30	.48	.....	.....	1.41	1.35	.45	1.11	6.21	.66	222.40
Farmers' National Bank-Page.....	19.60	5	.14	.16	.36	.72	.89	.....	2.27	3.75	1.60	2.09	9.17	.65	264.00
.....	11.60	5	.33	.40	.33	.44	.60	.....	2.10	1.84	1.58	1.73	8.07	.78	230.00
Carpenter-McMurray.....	4.42	3	.37	.90	.58	.....	.....	.....	1.85	4.18	.99	1.85	5.95	.93	181.00
Carpenter-Lyning.....	7.95	2	.70	.54	.....	.....	.....	.....	1.24	4.75	.40	.55	1.75	.67	196.00
Charles F. Mason.....	17.20	6	.47	.27	.30	.31	.40	0.30	2.05	4.02	2.81	3.65	20.90	.97	250.00
Minor-Wilson.....	6.23	2	.61	.54	.....	.....	.....	.....	1.15	2.00	1.94	1.94	6.65	.94	147.00
.....	8.04	2	.63	.57	.....	.....	.....	.....	1.20	2.13	1.75	1.93	6.33	.70	216.00
Total.....	157.29	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Average.....	12.10	4.05	.38	.38	.32	.53	.58	.30	1.71	.....	.....	1.95	9.17	.71	242.68
Maximum.....	.....	6	.....	.....	.....	.....	.....	.....	2.27	4.75	.....	3.65	20.90	.97	344.00
Minimum.....	.....	2	.....	.....	.....	.....	.....	.....	.74	.....	.40	.55	1.75	.58	48.00

TABLE 26.—*Irrigation of potatoes in 1917.*

Farm.	Area of field (acres).	Number of irrigations.	Water applied each irrigation (feet).						Total depth applied (feet).	Flow in second-feet.			Acres irrigated per 24-hour day.	Ratio hours attended to hours run.	Yield per acre (bushels).
			First.	Second.	Third.	Fourth.	Fifth.	Sixth.		Maximum.	Minimum.	Average.			
R. D. Hughes.....	25.10	3	0.41	0.52	0.11	.....	.....	.....	1.04	2.90	1.80	2.68	15.31	0.99	271.00
.....	15.20	4	.66	.39	.36	0.38	.....	.....	1.79	2.90	1.55	2.18	10.36	.75	309.20
Wilson-Campbell.....	11.81	4	.24	.32	.33	.42	.....	.....	1.31	2.70	1.00	2.00	12.12	.50	235.00
.....	43.45	3	.77	.45	.47	.....	.....	.....	1.69	5.00	.70	2.04	7.24	.54	235.00
Shafer-Uhrick.....	22.40	3	.69	.63	.42	.....	.....	.....	1.74	3.56	.15	2.00	7.00	.68	153.00
.....	3.69	3	.59	.14	.35	.....	.....	.....	1.08	.68	.55	.58	3.20	.60	154.00
Farmers' National Bank-Page.....	11.80	5	.33	.31	.51	.62	0.56	.....	2.33	2.00	.50	1.04	4.60	.72	204.00

RESERVOIRS.

The settlement of the Cache la Poudre Valley proceeded very rapidly after 1870 and the consequent extension of irrigation soon brought out the necessity for reservoirs. The stream was over-appropriated and as the irrigated area under early canals increased, the later canals suffered more and more from shortage of water. Conditions under the older canals became acute when continuous grain cropping had exhausted the land and the farmers were compelled to turn their attention to more profitable crops such as alfalfa, potatoes, and later, sugar beets. These crops required irrigation later in the season when water was available for only a few small ditches with early priorities. To meet these conditions the construction of reservoirs became general and has continued until nearly all the cultivated land of the valley is supplied to some extent with stored water. This is clearly shown in Plate XV, given to afford a comparison between the total area irrigated in 1916 and the area which received reservoir water that year.

With reference to organization, the reservoirs of the valley may be divided into 3 classes. The largest class is made up of small private reservoirs built by the individual to make the best use of a small head, to free himself from the limitations imposed by rotation periods, or to save a few acre-feet for a late irrigation. The second class includes the reservoirs which are owned as a part of a canal system and store water to be distributed as a part of the general supply. The majority of the reservoirs of this class belong to either the North Poudre Irrigation Co. or the Water Supply & Storage Co. The canals owned by these companies were constructed in 1881 and 1882 and as it was realized from the start that a sufficient supply of water could not be obtained by direct appropriation the construction of reservoirs was begun immediately. The third class includes the reservoirs owned by cooperative companies and supplying water to stockholders under canals which act as common carriers. Usually there is no legal connection between the reservoir company and the canal company, but in many cases a majority of the stockholders of the two companies are identical.

Reservoirs in the valley are supplied by natural streams; by seepage from canals, irrigated land, and other reservoirs; and by runoff from some normally dry catchment area during torrential rains. The great majority of the larger reservoirs take their supply from the Cache la Poudre and its tributaries, but a number are also supplied wholly or in part with foreign water. With the extension of irrigation, seepage from canals, reservoirs, and irrigated lands becomes important as a source of supply and many small reservoirs are now almost wholly dependent upon it. Only a few reservoirs are de-

pendent on the direct run-off from torrential rains, but most of this run-off is caught and stored.

The majority of reservoir sites were natural depressions or basins on bench land which were developed by putting the outlet in a cut, throwing up an embankment along the lowest rim, and constructing short inlet and outlet canals, connecting with distributing canals. These sites were the most satisfactory to be found, and were developed at a very low cost, running in one instance to \$1.09 per acre-foot of capacity. Sites developed by the construction of a dam across a drainage channel which carries regularly little or no water are almost as numerous. They differ from the ordinary stream-bed reservoir in that they are filled from some nearby source through an inlet canal and their dams are rarely protected with spillways. Reservoirs in the channels of flowing streams are few in number, because more satisfactory and cheaper sites are usually available elsewhere. The majority of the sites developed were small, with rather steep slopes, the average capacity per foot of depth being close to 130 acre-feet. Bottoms vary from light soils through which there is considerable seepage to a compact clay loam which is practically impervious.

The dams are, almost without exception, earth fills, varying in height from 10 to 40 feet, set on earth foundations. In general the site of the dam was first cleared of all brush, roots, and stones, and then plowed, after which the material was put on in layers, levelled, sprinkled, packed, and then harrowed to form a bond with the layer above. Some of the first dams were carried up in layers as thick as 5 feet, but as the practice improved the layers were reduced to a foot in thickness. The travel of the teams was depended upon, usually, to do the packing.

An exception to the common type of dam in the valley is the Halligan Dam of the North Poudre Irrigation Co. shown in Plate XVI, figure 1. This is an arched concrete structure which impounds 6,428 acre-feet of water in the bed of the North Fork. Its length at the top is 350 feet and at the bottom 235 feet. The thickness ranges from 30 feet at the bottom to 3 feet at the top. The total height of the structure is 94 feet, and the depth of water stored is 69.8 feet. A spillway is located in the middle of the dam. It is 110 feet wide, 10 feet below the top, and has a curved lip designed to prevent the overflow from leaving the face of the dam under anything less than an 8-foot head. The lower 67 feet of the dam is cyclopean masonry, rock masses not exceeding 2 cubic yards in volume being imbedded in a 1:3:5 concrete, reinforced with steel bars. Because of the poor quality of the rock available the upper 27 feet of the dam is of straight 1:3:6 concrete reinforced with bars. The total cost of the dam was \$230,000, which is at the rate of approximately \$36 per acre-foot of capacity.

The earth embankments are of various dimensions. Crests are from 8 to 16 feet wide and usually carry a roadway. Outer slopes range between 2 to 1 and 4 to 1. Inner slopes are steep or flat, depending on whether they are well protected against wave action. The slopes paved with concrete are usually 1 to 1 or $1\frac{1}{2}$ to 1, while slopes with no protection are often as flat as 4 or 5 to 1. The freeboard maintained on the dams ranges from 1 to 15 feet and is usually a compromise between water requirements and safety. When possible it is the custom to fill the reservoirs only partly full in the early spring to permit them to pass through the period of high winds with a safe freeboard. After the danger from high winds is past they are topped out and the water is raised to a point on the dam which would be decidedly unsafe under a continued high wind.

The erosive action of waves on earth embankments, illustrated in Plate XVI, figure 2, is so destructive that some sort of protection is always provided if possible. A few of the smaller dams are protected by brush laid on the slope and held by stakes and wire. Many are protected by a loose rock riprap laid on the upper part of the slope, where wave action is most destructive. On the whole, this protection seems to give as much satisfaction as any. Its chief fault is that the rock is continually settling and slipping down the slope, making it necessary to add more rock until a condition of stability has been reached. In the case of the Cache la Poudre Reservoir more or less rock has been dumped on the slope every year for 20 or 25 years and a condition of strict stability has not yet been attained. A few slopes are protected by a rock riprap hand laid on a cushion of gravel. This type is also subject to dislodging and settling, and requires considerable repair work to keep it in good shape. A number of dams are protected by concrete pavements about 6 inches in thickness and reinforced with wire mesh or iron rods. Some of these are laid on in sheets without joints, but the majority are in strips running from toe to crest. A few are supported by ribs running up and down the slope at intervals. Owing perhaps to the short slopes covered, there have been no total failures of this type so far, but local failures are common. These failures start with cracks opened by expansion and contraction through which the water is able to dig a cavity in the slope under the pavement. After these cavities are formed it is supposed that the force of the waves either smashes in the unsupported pavement over the cavity or compresses the air in the cavity sufficiently to produce an outward bulge of the pavement and consequent failure. Plate XVII, figure 1, shows a break in the pavement of Terry Lake resulting from a crack.

As the great majority of the reservoirs in the valley are supplied through canals and with few exceptions the drainage area immediately above develops only a small amount of water, wasteways are

not considered necessary. The few that have been provided are simple makeshifts, usually depressions a foot or two above high water line which are left without embankment. The few dams in stream beds are of course properly equipped with spillways.

Outlets are either lines of tile or iron pipe or conduits of masonry or concrete. The pipe lines are all laid in concrete and are provided with concrete collars to cut off seepage. The masonry conduits are generally embedded in concrete and rest on solid foundations of concrete or masonry and concrete from $1\frac{1}{2}$ to 5 feet in thickness. Gate wells are ordinarily at the top of the inner slope, as gates set either at the upper or lower end of the conduit have proved to be less satisfactory. Plate XVII, figure 2, shows the gate tower of the North Poudre Reservoir No. 15 blasted out after it had been replaced by a well within the dam as shown. This was done as a matter of precaution upon order of the State engineer after a similar structure in Lake Loveland had been destroyed by ice pressure. Many of the reservoirs have no gate wells, the gate stem being brought up through the dam in 4 or 6 inch cast iron pipe. Gates are of various types, including iron-strapped wooden gates, sliding iron gates, and other more pretentious valves. Lifting devices are all some standard combination of screw and lever.

The total capacity of the reservoirs of the valley is over 150,000 acre-feet. The largest is the Windsor Reservoir, which holds between 17,000 and 18,000 acre-feet, and from this size they range downward to many which hold less than 5 acre-feet. Some have never been surveyed to determine their capacities, and little dependence can be placed in the capacity tables of a majority of those which have been surveyed. The work was often done in such a manner that errors show on the face of the table, indicating in one case that the reservoir for a few feet of its depth took the shape of an hourglass. It is believed that accurate capacity tables based on reliable surveys would aid materially in the operation of the canals carrying reservoir water and would eliminate to a great extent inequalities in exchanges and in the distribution as well.

The very low first cost of the majority of reservoirs in the valley is indicated by the figures shown in Table 28, which, with the exception of the average, are reproduced from a bulletin by C. E. Tait, issued by the U. S. Department of Agriculture in 1903.¹⁰ The Fossil Creek and Cache la Poudre Reservoirs run much above the average for the reason that each required a high and long dam across a valley. The sites of North Poudre No. 2, North Poudre No. 3, and Coal Creek Reservoir were developed at such a low cost because they were natural basins requiring only an outlet in a cut

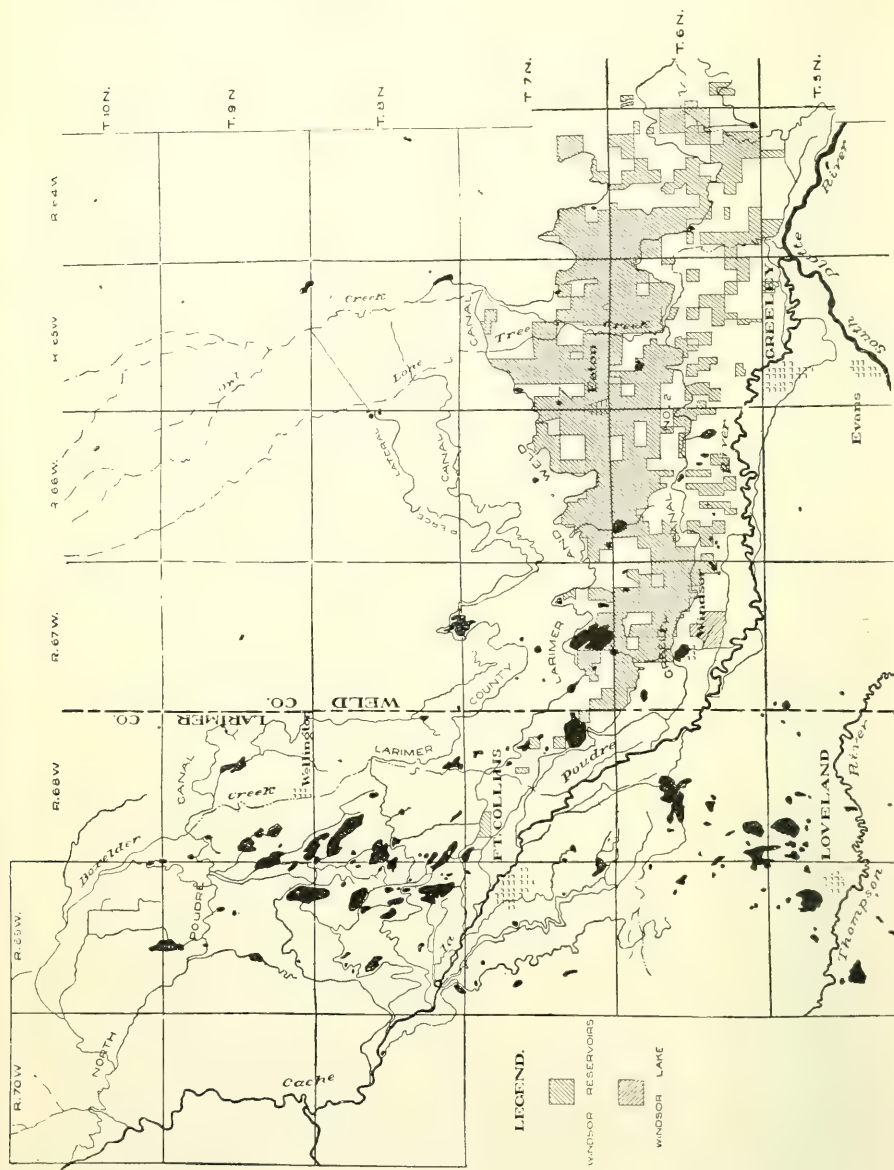
¹⁰ Storage of Water on Cache la Poudre and Big Thompson Rivers, by C. E. Tait, U. S. Dept. Agri., O. E. S. Bul. 134.



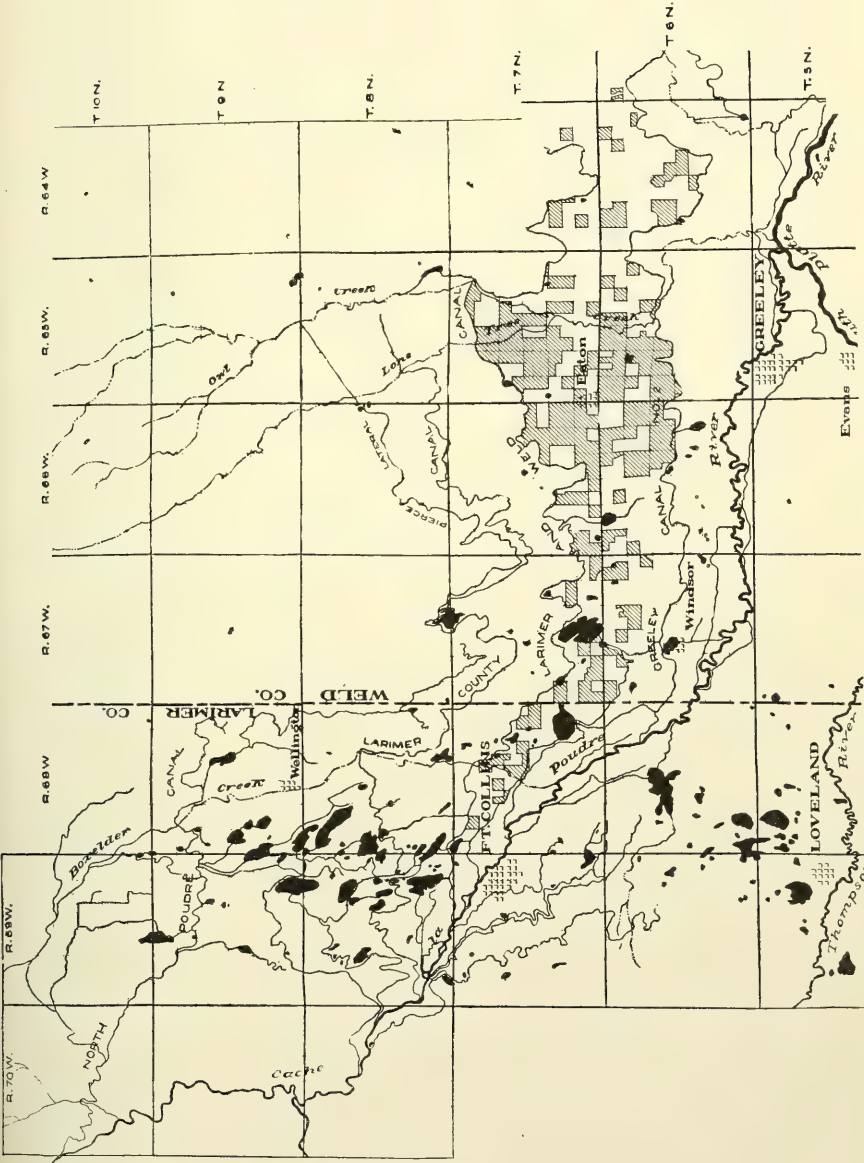
FIG. 1.—CLOSE VIEW OF BREAK IN THE PAVEMENT OF TERRY LAKE.



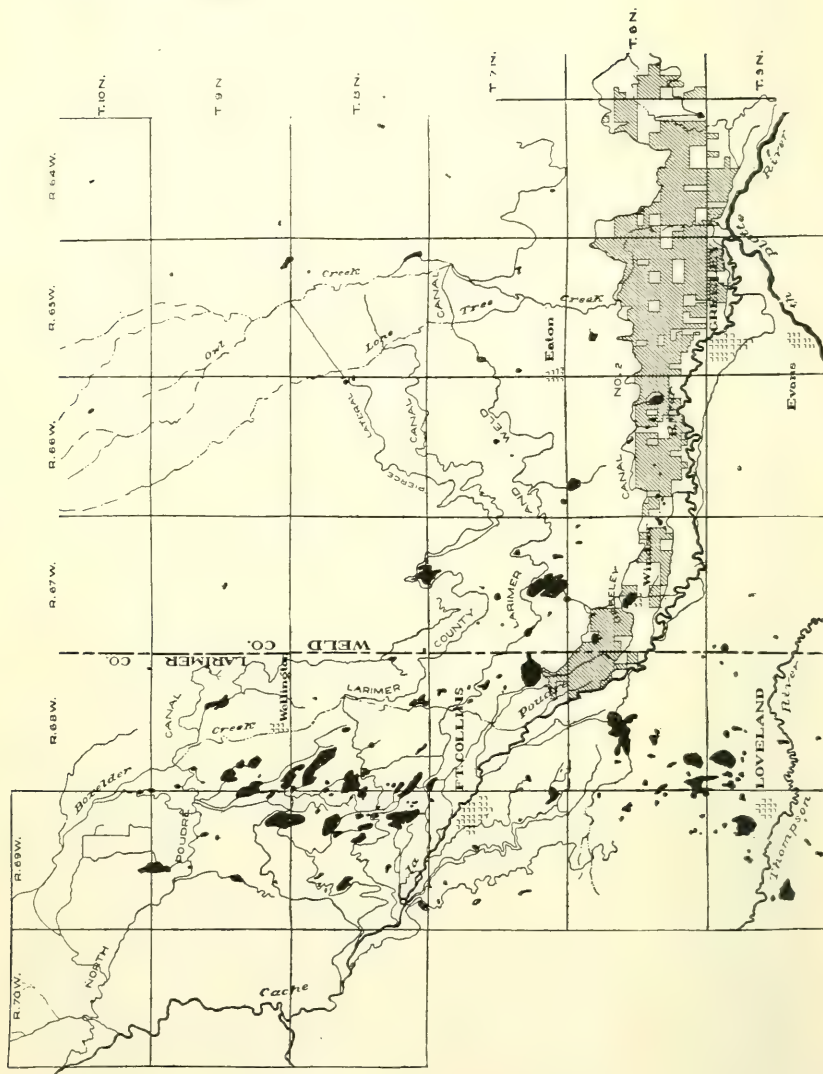
FIG. 2.—GATE TOWER BLASTED OUT AND REPLACED BY A WELL WITHIN THE DAM. NORTH POUDRE RESERVOIR No. 15.



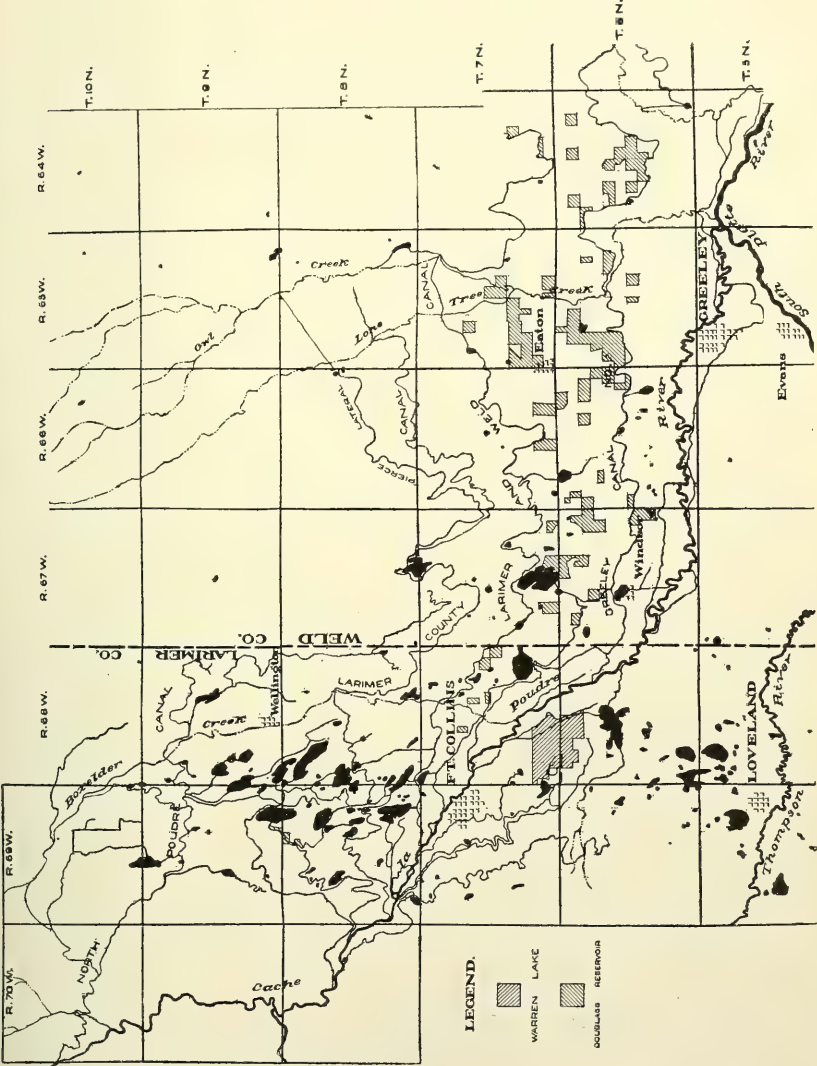
AREAS SERVED IN 1916 BY THE WINDSOR RESERVOIR AND WINDSOR LAKE



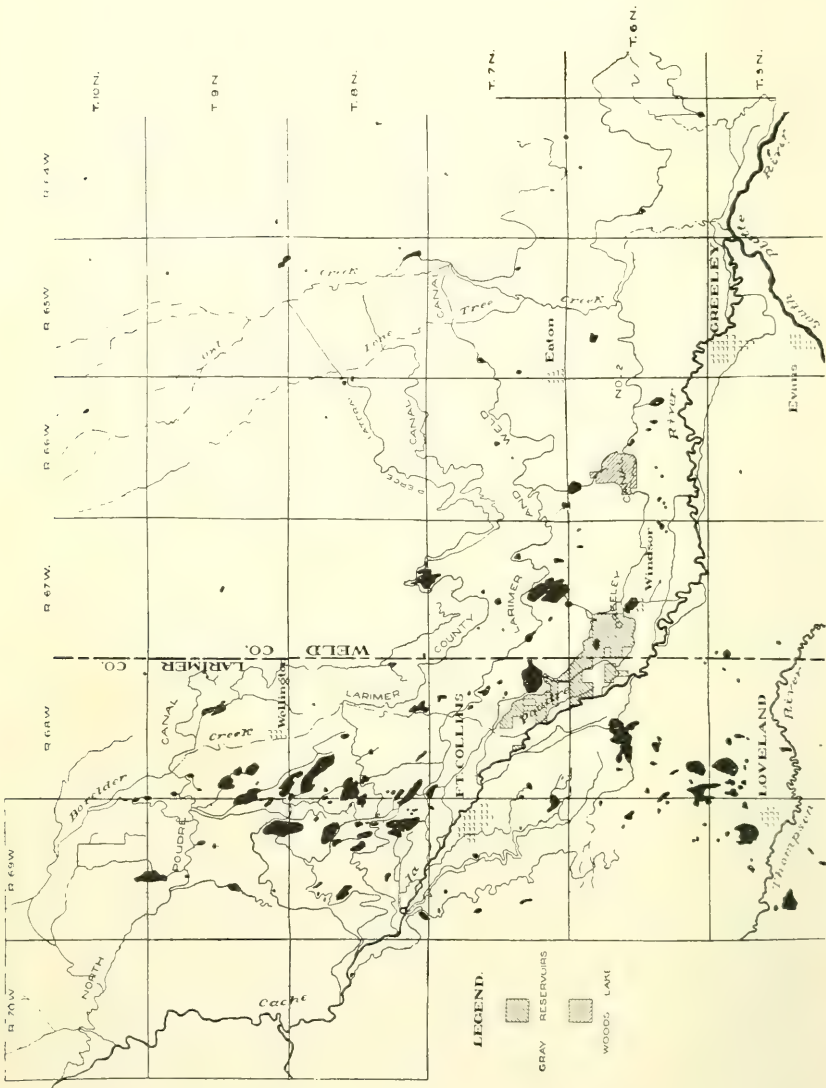
AREAS SERVED IN 1916 BY TERRY LAKE.



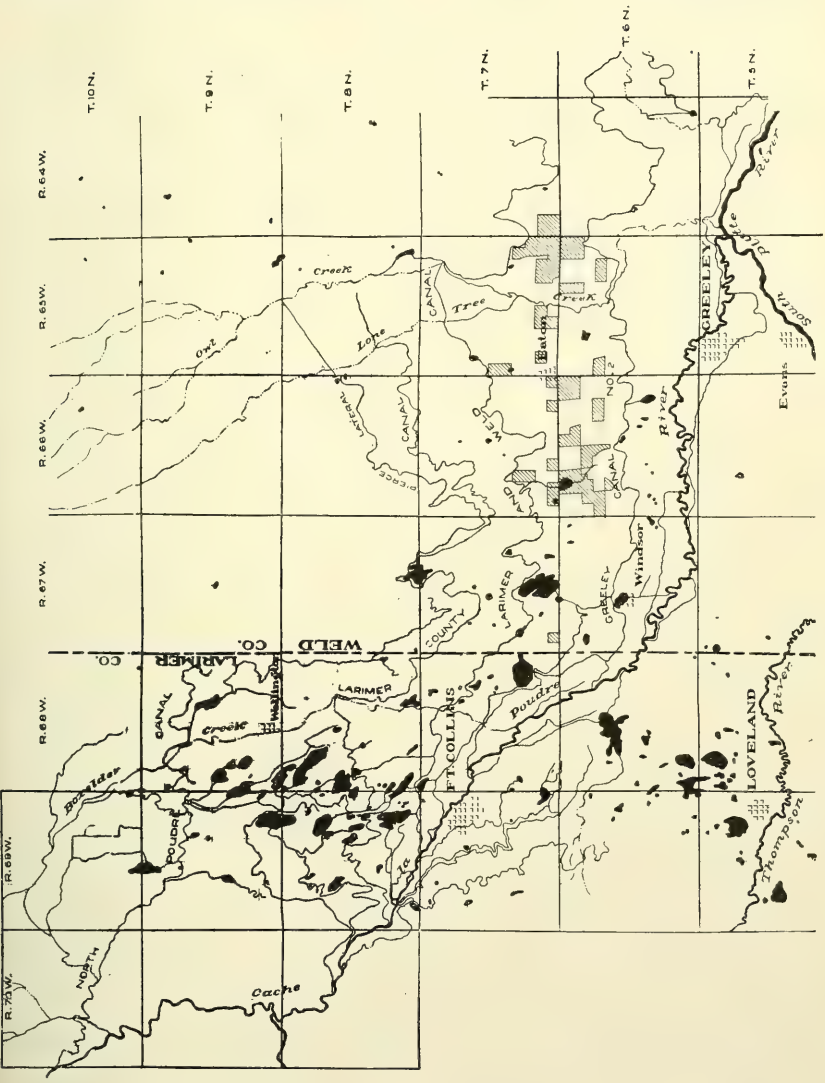
AREA SERVED IN 1916 BY THE CACHE LA POUDRE RESERVOIR.



AREAS SERVED IN 1916 BY WARREN LAKE AND DOUGLAS RESERVOIR.



AREAS SERVED IN 1916 BY THE GRAY RESERVOIR AND WOODS LAKE.



AREA SERVED IN 1916 BY THE WORSTER RESERVOIR.

and a small embankment. Some of these reservoirs have been enlarged since 1903 and the cost to date would give a lower unit cost than is shown by the table.

TABLE 28.—*First cost of reservoirs of the valley.*

Reservoir.	Cost.	Capacity in acre- feet.	Cost per acre-foot.
Cache la Poudre No. 2.....	\$105,000	8,035	\$12.07
Terry Lake (Larimer and Weld).....	70,000	6,887	10.16
Windsor Reservoir.....	50,000	11,708	4.27
Rocky Ridge.....	12,000	4,726	2.54
Long Pond.....	12,000	3,922	3.06
North Poudre No. 1.....	3,000	674	4.45
North Poudre No. 2.....	7,500	5,000	1.50
North Poudre No. 3.....	5,000	2,550	1.96
North Poudre No. 4.....	5,000	1,074	4.66
Coal Creek (Clark's Lakes).....	6,000	4,477	1.34
Fossil Creek.....	160,000	11,478	13.94
Douglass.....	50,000	10,547	4.74
Windsor Lake.....	1,000	918	1.09
Average.....			6.75

The sale of reservoir water and the rental of rights for a season is a common practice in the valley. Many reservoirs are owned by individuals and were built expressly for the purpose of selling the water stored in them, while others are owned by cooperative companies which impose no restrictions as to where the water may be used. Many farmers own an excess of rights in these reservoirs, and others have an excess when their scheme of rotation of crops brings them around to a year in which they have a preponderance of crops requiring only early irrigation. To offset this supply there is always more or less demand from farmers who have not quite enough water for ordinary conditions and who suffer from a real shortage in dry weather, or from farmers who have a sufficient supply in average years but who are growing a large acreage of crops requiring heavy late irrigation. In ordinary years under the Greeley Canal No. 2, a second-foot for 24 hours will sell for \$5, and there will be an additional charge of \$1 for carriage in the canal, but in dry years the price may be as much as \$16 per second-foot for a day. Rights in Terry Lake, carrying between 45 and 50 acre-feet per season, have rented for from \$40 to \$300, but the average charge is close to \$75. North Poudre shares, carrying $1\frac{1}{2}$ to $2\frac{1}{2}$ acre-feet, average about \$10 per season. It is natural that under these conditions there should be a certain amount of speculation. In the early spring the speculator buys water or rents rights to be held and later rented or sold to others. Whether he makes or losses depends chiefly on the dryness of the season. Water for which he paid \$2 an acre-foot may sell for \$8 or \$10, or there may be no market at all for it.

The land served in 1916 by the more important independent reservoirs of the valley is shown in Plates XVIII to XXIII, inclusive.

Water stored in reservoirs owned by canal companies is used on the same land as the direct flow of the canals, and these areas are shown in another section of this report. An estimate of the acreage actually irrigated by the independent reservoirs is given in Table 29.

TABLE 29.—*Estimate of acreages actually irrigated by independent reservoirs of the valley in 1916 and 1917.*

	1916						1917					
	Alfalfa.	Sugar beets.	Potatoes.	Beans.	Miscellaneous.	Total.	Alfalfa.	Sugar beets.	Potatoes.	Beans.	Miscellaneous.	Total.
Windsor Reservoir.....	18,663	9,741	5,443	4,096	.....	37,943	14,647	5,227	9,182	5,734	.....	34,790
Terry Lake.....	9,740	4,252	3,519	1,655	.....	19,166	7,358	2,323	5,022	2,395	.....	17,098
Cache la Poudre Reservoir.....	10,511	7,160	1,835	2,564	.....	22,070	9,818	4,324	4,078	3,993	40	22,253
Douglass Reservoir.....	4,078	2,244	1,244	1,034	.....	8,600	2,358	816	1,136	791	.....	5,101
Warren Lake.....	1,330	681	.....	9	17	2,037	1,485	656	2	4	19	2,166
Gray Reservoirs.....	1,741	1,336	35	74	.....	3,186	1,696	1,161	76	78	2	3,013
Worster Reservoir.....	3,126	1,450	872	503	.....	5,951	3,807	1,503	2,344	1,233	.....	8,887
Woods Lake.....	329	168	161	82	.....	740	252	198	222	231	1	904
Windsor Lake.....	186	439	.....	30	.....	655	152	303	23	34	.....	512
Dowdy Reservoir.....	126	45	.....	12	.....	183	364	156	206	154	.....	880
Hour Glass Reservoir.....	236	155	194	102	.....	687	.....	.....	.....	.....	.....	.....
Zimmerman Reservoir.....	106	111	52	.....	.....	269	.....	.....	.....	.....	.....	.....
Greeley-Poudre Water.....	536	238	104	324	.....	1,202	376	65	232	263	.....	936
Fossil Creek Reservoir.....	2,920	2,063	700	1,155	.....	6,838	2,794	1,178	1,472	1,579	.....	7,023

Stored water is used for irrigation during every month of the season, but the greater part of it is used from July 20 to September 10, as the supply received on direct appropriations falls off. The amount of stored water used in 1916 and 1917 is shown in Table 30, which is taken from Tables 10 and 11 on pages 44 and 45. The large amount used in August, 1917, was due to a supply greatly in excess of the normal.

TABLE 30.—*Reservoir water used by canals of the valley in 1916 and 1917.*

	1916		1917	
	Amount used (acre-feet).	Per cent of total.	Amount used (acre-feet).	Per cent of total.
April.....	353	.....	.....	.....
May.....	6,978	8	182	.....
June.....	6,639	8	2,358	2
July.....	27,098	30	13,713	14
August.....	32,149	35	60,224	63
September.....	17,373	19	20,890	21
Total.....	90,590	100	97,367	100

ABSORPTION LOSSES.

In arriving at the absorption loss for reservoirs of the valley, reliable records of the following were used: Windsor Reservoir, Douglass Reservoir, Cache la Poudre Reservoir, Terry Lake, North

Poudre Reservoir No. 15, Woods Lake, Kluver Lake, Curtis Lake, Claymore Lake, Water Supply and Storage Co. Reservoir No. 4, and Dealy Reservoir. These reservoirs afforded a range in surface area up to 1,000 acres, in depth up to 40 feet, and in volume up to 17,500 acre-feet. Records were kept of the operation of all the more important reservoirs of the valley, but many of these records were not suitable for computing absorption losses and were discarded. No capacity tables were available for a number, and time could be found to survey only a few of these. Other records covering periods of inflow and outflow were discarded on account of the poor conditions at the measuring stations on the inlet and outlet canals. Thus in the case of Terry Lake the rating stations on both inlet and outlet were subject to backwater conditions and for that reason the only records of Terry Lake used in computing losses were those made during periods of no inflow nor outflow.

Table 31 is given to show the method used in computing the loss, and practically explains itself. In estimating the increase in the reservoir by rainfall it was necessary to use the rainfall records at Fort Collins, which is as much as 15 miles from some of the reservoirs, together with the area at the high water line and the probable run-off from the drainage area above. For this reason some of the periods overlap, the shorter excluding rains which show in the longer period and serving as a check.

The average absorption loss is shown by curves in figures 14, 15, and 16, in which the loss in acre-feet per day is plotted against the depth, area, and volume. The curves are based on more than 200 points, each of which represents the loss in a single reservoir for a period of from 3 to 30 days during the spring and summer months.

TABLE 31.—*Absorption losses from Claymore Lake.*

Period.	Days.	Reservoir gage at beginning.	Reservoir gage at end.	Average depth (feet).	Average surface area (acres).	Average volume (acre-feet).	Stored at beginning (acre-feet).	Increase by rainfall (acre-feet).	Total (acre-feet).	Stored at end (acre-feet).	Absorption losses.			
											Total (acre-feet).	Per day (acre-feet).	Cubic foot per square foot of surface per day.	Per cent of volume per day.
1916.														
June 1-28.	27.31	14.54	13.77	14.16	79.0	893.3	923.6	4.2	927.8	862.9	64.9	2.38	0.030	0.266
June 14-28.	13.98	14.21	13.77	13.99	78.6	880.3	897.6	.....	897.6	862.9	34.7	2.48	.032	.282
1917.														
May 8-26.	18.00	14.78	14.65	14.70	80.3	936.2	939.8	18.5	958.3	932.6	25.7	1.43	.018	.153
May 12-19.	7.00	14.66	14.53	14.60	80.0	928.1	933.4	.....	933.4	922.8	10.6	1.51	.019	.163
June 2-30.	28.00	14.70	14.08	14.39	79.6	912.0	936.6	.....	936.6	887.3	49.3	1.76	.022	.193
July 4-28.	24.00	13.99	13.50	13.75	78.1	861.0	880.3	6.0	886.3	841.7	44.6	1.86	.024	.216
July 11-21.	9.85	13.91	13.64	13.78	78.1	863.4	874.0	.....	874.0	852.7	21.3	2.16	.028	.250
Aug. 1-11.	10.04	13.38	13.11	13.24	76.9	822.2	832.5	.2	832.7	811.9	20.8	2.07	.027	.252

The amount of storage required for any particular canal depends on the amount of water produced by the direct flow rights at various times throughout the season and on the kinds of crops grown. This is shown by data for 1916 and 1917 for the four largest canals of the valley in Table 32. The comparatively small amount of stored

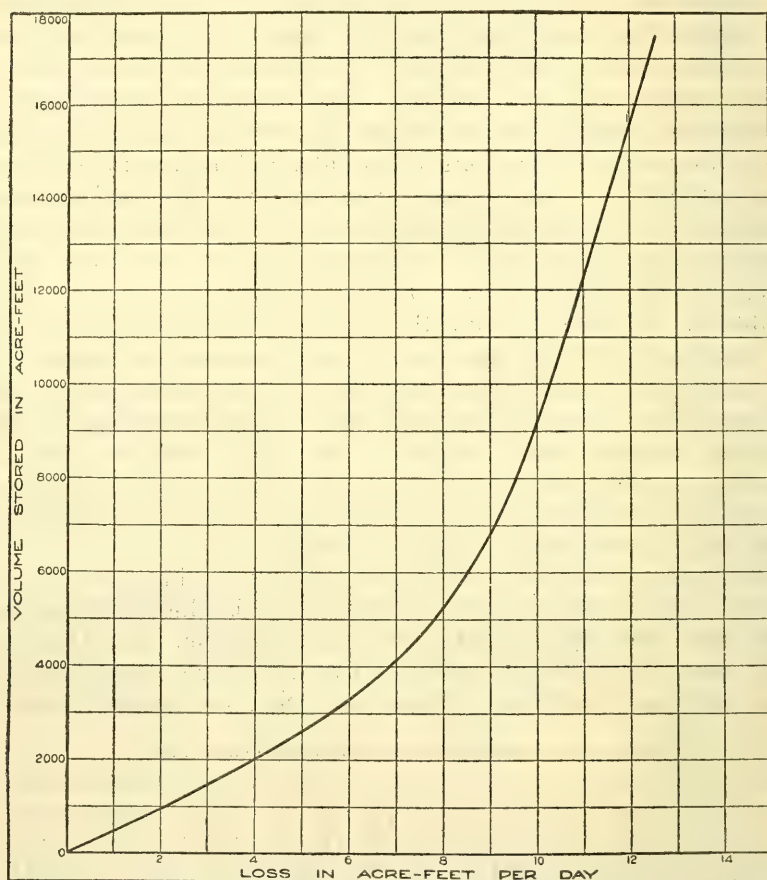


FIG. 14.—Absorption losses in reservoirs. Relation between the volume stored and the loss.

water required by the Larimer County Canal is due to the fact that the greater part of its deficiency on direct appropriations is made up by foreign water. In the case of the North Poudre Canal the supply was short and more reservoir water could have been used to advantage.

TABLE 32.—Comparison of stored and direct flow water used by four of the largest canals of the valley in 1916 and 1917.

Canal.	Priority No. of principal appropriation.	Water used.		Storage as per cent of total.
		Direct flow acre-feet.	Storage acre-feet.	
1916.				
Greeley Canal No. 2.....	37	54,908	13,458	20
Larimer and Weld Canal.....	88	67,166	23,926	26
Larimer County Canal.....	97	49,876	22,111	31
North Poudre Canal.....	98	16,169	25,188	61
1917.				
Greeley Canal No. 2.....	37	53,383	14,617	21
Larimer and Weld Canal.....	88	67,889	29,547	30
Larimer County Canal.....	97	64,692	19,274	23
North Poudre Canal.....	98	20,745	28,954	58

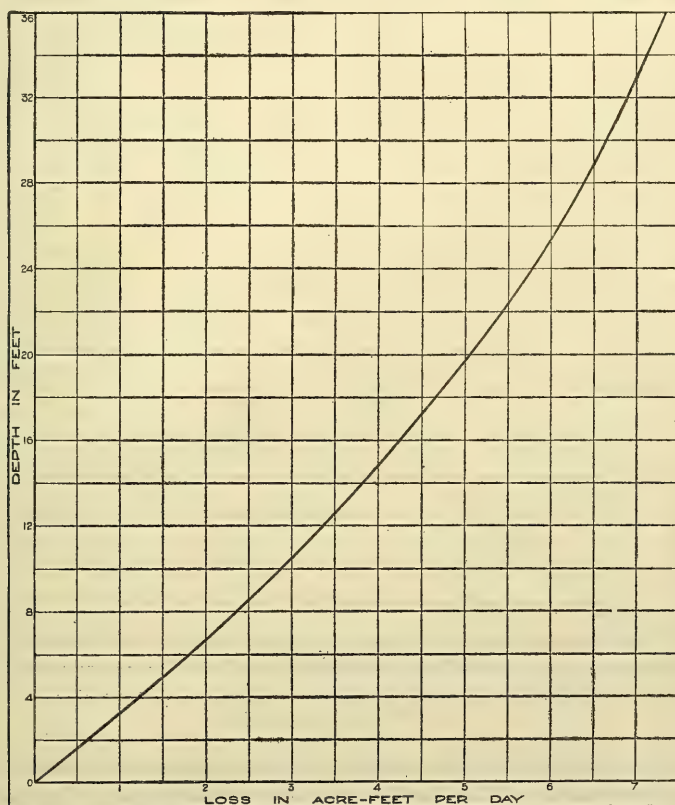


FIG. 15.—Absorption losses in reservoirs. Relation between the depth and the loss.

FARM RESERVOIRS.

A large number of reservoirs of the valley may be properly classed as farm reservoirs. They are owned by the individual farmer and are used by him to hold temporarily his supply of water from some

canal or to collect some small seepage stream to make it available for irrigation.

A typical reservoir of this class is owned by M. W. Dealy and supplies a part of his farm 7 miles northwest of Fort Collins. It is 8.6 feet in depth, covers 7.6 acres at the high-water line, and has a capacity of 26.6 acre-feet. The outlet gate of the reservoir is shown in Plate XXIV, figure 1. The dam is several hundred feet long, 8.5 feet

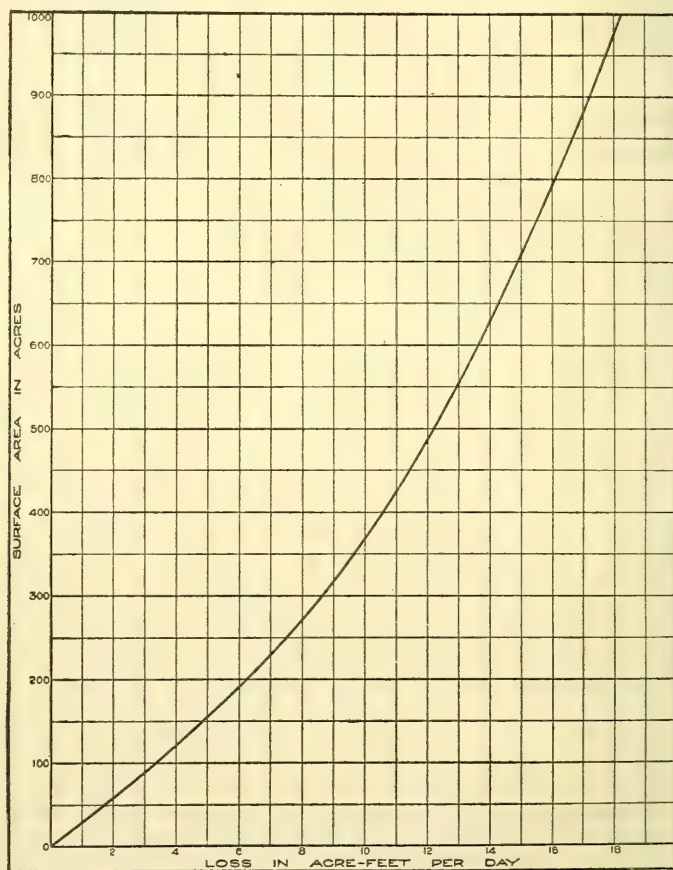


FIG. 16.—Absorption losses in reservoirs. Relation between the surface area and the loss.

high, and 10.5 feet above the outlet. The inner slope is rippapped with loose rock extending 5 feet below the high-water line. The outlet is 12-inch vitrified pipe set in a concrete bulkhead at each end. The gate is a common type of sliding iron gate. The reservoir was built in 1908 and cost \$930, or at the rate of \$35 per acre-foot of capacity.

Its water supply comes from the Larimer County Canal. A part of the Dealy farm is served by the Jackson Ditch, but a part lies above this ditch and is commanded only by the Larimer County Canal

of the Water Supply & Storage Co. In order to get a water supply for it, Dealy entered into a contract with the Water Supply & Storage Co. by the terms of which the company acquired half a share of stock of the Jackson Ditch from Dealy and Dealy acquired the right to a certain amount of water from the Larimer County Canal from April 15 to September 15 of each year. The contract provides that the amount delivered shall be approximately 17 per cent less than the amount per half share delivered by the Jackson Ditch the same day. When the Jackson Ditch draws all its appropriations a share represents 120 statute inches; therefore, the maximum amount Dealy is entitled to draw is 50 inches. Shortly after Dealy finished his reservoir the owner of an adjoining farm made a similar contract with the Water Supply & Storage Co. and purchased from Dealy a right to carry his water through the Dealy ditches. This water is carried directly through the reservoir.

During the season 1916, from May 8 to September 7, the Larimer County Canal delivered to the reservoir 211 acre-feet at a rate not exceeding 2.12 second-feet. This was sufficient to fill the reservoir eight times. The loss in the reservoir during the season was 39 acre-feet, or about 18 per cent of the total supply, including 4 acre-feet of rainfall and run-off. During the season 176 acre-feet were drawn from the reservoir for the irrigation of 99.3 acres of grain and alfalfa. The rate of use ran as high as 9.20 second-feet but averaged 5.44 second-feet for alfalfa and 3.25 second-feet for grain.

The difference in inflow and outflow noted above and illustrated in Plate XXIV, figures 1 and 2, reveals the chief benefit derived from these small reservoirs. A very high duty is obtained by storing streams of ditch and seepage water entirely too small for practical use and when the water is needed turning it out in large heads for effective and economical irrigation.

SUMMARY AND CONCLUSIONS.

The characteristics of the climate of the valley are a light rainfall, a wide range in daily and seasonal temperature, low relative humidity, moderately high wind movement, and a comparatively low rate of evaporation. The heaviest rainfall occurs in the spring and is usually sufficient to start the crops growing under natural conditions without resorting to irrigation to bring up the crops.

The prevailing type of soil is a light sandy loam, which is generally well drained. Excepting local phases, the texture of this soil is such that it is easily irrigated and at the same time it retains moisture well. The average depth of water applied for an irrigation is close to .75 foot, but the average is raised somewhat by the heavier irrigations applied when direct flow water is available in order to reduce the later requirements of stored water. Considering the soil

alone, best results would be obtained by quick irrigation to a depth of 0.4 to 0.6 foot.

The water supply of the valley averages 464,000 acre-feet, which includes 340,000 acre-feet of normal run-off in the river and its tributaries, 35,000 acre-feet of foreign water, 5,000 acre-feet pumped from wells, and available seepage return to the amount of 84,000 acre-feet. Practically the whole supply is taken; and further projects, either for direct flow or for storage, are probably not feasible.

The regimen of the river largely controls the cropping system of the valley. The flood stage of the stream occurs at such a time that the irrigation of at least a third of the acreage in crops, chiefly grain, may be completed with water drawn directly from the river. This leaves the stored water to be used for maturing such valuable crops as sugar beets, potatoes, etc.

The foreign water brought into the valley from other drainage basins is collected from the highest slopes of the mountains, and it therefore comes down after the peak of the flood has passed. This supply is comparatively small but it is very vital to both the North Poudre and Larimer County canals. It becomes available shortly before their main appropriations are cut off and makes it possible to delay for from one to three weeks the time when almost the whole demand must be met with stored water.

The total seepage return in the valley is 137,000 acre-feet, which is approximately 36 per cent of the normal water supply (exclusive of seepage). The topography is such that a large proportion of this seepage return is available for use, and it plays an important part in irrigation in the valley. The high percentage of return indicates that when the return reaches the maximum on other streams many water rights, both direct and storage, which are now not dependable, will become good. The certainty and uniformity of this supply will produce results comparable to those produced by stored water.

Drainage is not a serious problem in the valley. Only local areas have become too wet, and corrective measures have always been promptly applied.

By the system of exchange of water developed in the valley 50,000 acre-feet of stored water is made available for use in canals above the reservoirs. To this system may be attributed the use of a number of sites capable of cheap development. Incidentally, as perfected in the valley, the system promotes a better distribution from the river and vastly improves conditions under which the canals operate by largely confining the daily fluctuation of the river to one of the larger canals where it can be "smoothed down" by the use of reservoirs as regulators. In addition, the pooling of interests required by the exchange has brought about a better understanding between the canal men of the valley and there is now a tendency to get to-

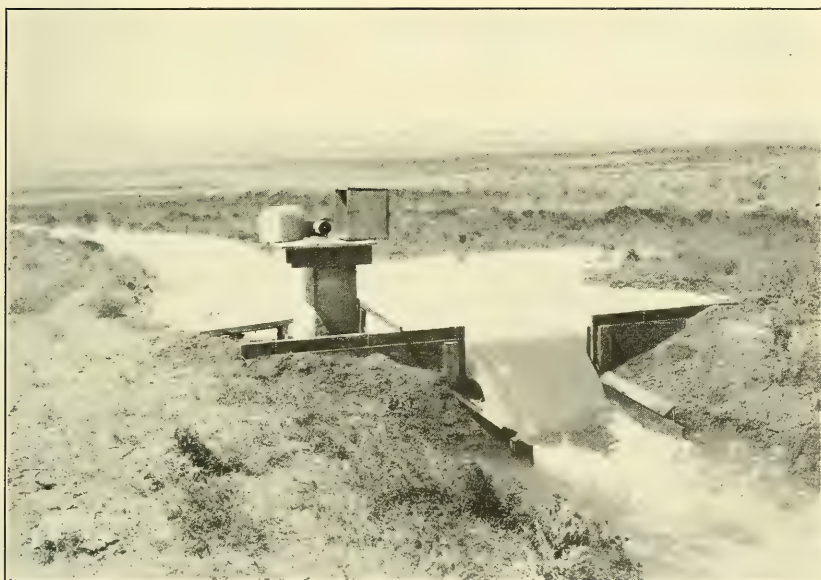


FIG. 1.—WEIR ON THE OUTLET OF THE DEALY RESERVOIR. AVERAGE OUTFLOW.

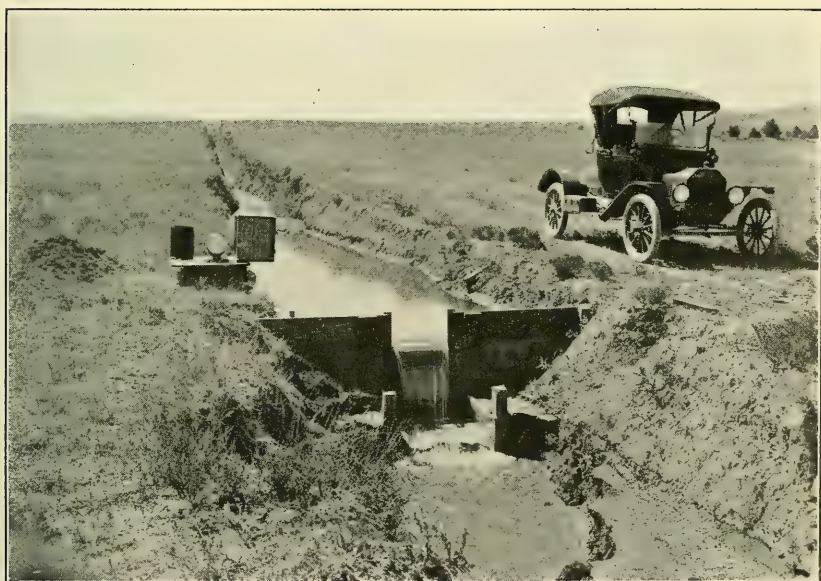


FIG. 2.—WEIR ON THE INLET OF THE DEALY RESERVOIR.

gether and talk over differences before resorting to the law. There is no doubt that the practice of exchanging water had its effect in getting the canal men of the valley in the habit of measuring water. While conditions of which the system is an outgrowth will probably never be duplicated, the principles and methods involved might be advantageously applied for a solution of problems elsewhere.

The majority of direct flow rights of canals were established by decree of the district court in 1882 and these rights remain practically unchanged. Storage rights were fixed by decree in 1909. There can be no question that the early fixing of rights had a strong influence on the later development of irrigation. The canal owners whose decreed rights were good went ahead with their development and expansion secure in the feeling that they would be protected in their rights. The two late appropriators of large amounts were clearly shown the inadequacy of their rights and lost no time in devising means of supplementing their supplies. This led at once to the construction of reservoirs and later to the development of supplies of foreign water.

In the aggregate, capacities of the canals exceed by 10 per cent their appropriations. The extension of land irrigated has been such that the originally excessive decrees of the larger canals are now utilized. Excessive rights are still held by several small ditches along the river bottoms. These ditches divert a comparatively small amount, of which a great part returns directly to the river and is diverted below by canals with early rights.

Many transfers of appropriations from one canal to another have been made, but the amounts transferred, especially of the earliest rights, were small. These transfers have in general resulted in little damage to other appropriators and in much benefit to the canal to which the transfer was made.

Almost without exception distribution from the river is made in accordance with decreed priorities. The exceptions to the rule are recognized as legitimate by the canal men of the valley. Besides fearlessness and tact, the distribution of water from a stream requires an intimate knowledge of the handling of water in general and of the peculiarities of the particular stream itself. The water commissioner's handling of the Cache la Poudre for more than a score of years is most convincing evidence that the administrator of a stream should not be subject to the fortunes of a political party and that when a good man is secured he should be kept in office. It is folly to expect an inexperienced man to handle satisfactorily the problems of distribution which constantly arise, especially as complicated by return water and private water carried in natural channels. The obvious remedy is a study of the streams of the State by experienced

engineers and hydrographers to determine losses and gains in the streams, the return flow, characteristics of flow peculiar to each stream in flood and at low stages, and other pertinent facts. With this information at the disposal of the administrator a fairly satisfactory distribution would be possible immediately upon his taking office and not after 2 or 3 years of painstaking and perhaps costly experimenting.

The duty of water figured for the river as a whole is 1.67 acre-feet per acre; or, expressed differently, each second-foot of the average annual discharge irrigates 434 acres. This very high duty is made possible only by the reservoirs of the valley. To attain a duty as high without stored water, the crops grown would have to be limited to the grains.

The consumptive duty for the valley is estimated not to exceed 1.25 acre-feet per acre.

Nonproductive and waste land averages approximately 15 per cent of the area under irrigation.

The areas irrigated by the various canals lie in very compact bodies, which promotes to a pronounced extent the efficient use of the water supply.

The area actually irrigated in the valley proper in 1916 was 218,000 acres; in 1917, 225,700 acres. Any marked extension of the area irrigated is improbable.

The majority of the canals of the valley are cooperative enterprises and present no unusual features of organization. The fact that the majority were cooperative from the beginning has an important bearing on the development of the valley. Such systems were run for the mutual benefit of water users and there was very little of the paralysis of development caused elsewhere by overpromotion for profit.

The great majority of laterals serving more than 2 or 3 users are controlled by incorporated cooperative stock companies, and this form of organization for laterals is to be recommended. By it the delinquent water user can, in an impersonal way, be made to live up to his obligations.

Canal structures follow common designs and concrete is replacing wood for construction purposes. The systems of the valley have long since passed the stage of development where cheap construction was permissible in order to reduce first costs, to keep down interest charges, and to permit expansion. Future construction should be of the most substantial character.

The rating flumes of the canals are generally most unsatisfactory and should be replaced by structures better suited for the purpose. They should be of the same cross section as the canal and should neither constrict nor widen the channel. They should be on grade

and in a straight section of canal with no curves for some distance either above or below. The velocity through them should be sufficient to prevent the deposit of silt, but not high enough to produce waves. There should be no drop immediately below to produce standing waves. They should not be subject to backwater from movable checks, and they should not be placed close below gates which either do, or may be made to, discharge under pressure.

Maintenance problems are at a minimum. However, more attention should be paid to protecting canal banks from erosion, installing effective sand traps, and keeping delivery weirs in better order.

The distribution within the canal system of direct flow water is either by continuous delivery of a prorata part of the flow or by some system of rotation when the supply is short. The latter system is by far the most effective in producing a maximum benefit from a given supply. The other system is almost invariably a source of waste.

Reservoir water is delivered as a prorata part of the flow carried, or in rotation, or on demand. Delivery on demand produces the most effective use but at times the advantages must be weighed against difficulties of canal operation.

Many canals act as common carriers for reservoir water owned or rented by their stockholders. By a system of pooling of interests and switching of credits this water is delivered on demand of the individual.

Weirs are used for measuring water to the user but there is much room for improvement in their installation and maintenance.

The average gross duty of water measured at the head of all the canals of the valley was 1.88 acre-feet per acre in 1916 and 1.91 acre-feet per acre in 1917. Taken in connection with the consumptive duty of 1.25 acre-feet per acre, this indicates a total loss exclusive of evaporation of only a third of the supply.

The absorption loss in the canals of the valley between the head-gate and the farm lateral is estimated to average 10 per cent of the supply. This low figure is accounted for in part by the topography of the country and the location of the canals one above another. A considerable part of the gross loss is compensated by the inflow of seepage.

Seepage water is used to some extent on nearly the entire irrigated acreage of the valley; but the land dependent on it as a main supply is rather limited, unless we include that lying under the ditches which divert it after it has returned to the channel of the river.

Furrow irrigation and flooding from field laterals are the only methods of irrigation practiced. Best results are obtained by a fast irrigation to a depth of .4 to .6 foot. The layout of the field should be such that a thorough even watering is obtained, that there is a minimum of run-off at the lower end of the field, and that the depth

applied is light enough to prevent an undue loss by deep percolation. The head used should be governed by the conditions above and the soil. Large heads should be used when possible, as they save both time and water if handled properly.

The run-off from the lower end of the field averages 6 per cent of the amount applied. This is a very low average, but there are many farms where much improvement could be made along this line.

The average number of irrigations applied on the fields under investigation ranged from 1.21 for wheat to 3.79 for potatoes.

The average head used by one irrigator ranged from a minimum of 1.85 second-feet for sugar beets to a maximum of 2.59 second-feet for alfalfa.

The number of acres irrigated per day by one person ranged from an average of 4.45 for barley to 6.78 for potatoes. Beans were in an entirely different class with an average of 15.63 acres per day per man.

The average duty in acre-feet per acre, measured at the head of the farm lateral, was: Alfalfa, 2.57; wheat, 1.04; oats, 1.35; barley, 1.19; sugar beets, 1.86; potatoes, 2.20; beans, 0.69.

Reservoirs are by far the most important factor governing the good use of water in the valley. By their use water is made available when and only when needed. Without them an entirely different type of development would have resulted in the valley.

The large number of reservoirs was made possible by natural basins which could be developed with a minimum of trouble and expense. For thirteen of these reservoirs with an aggregate capacity of 72,000 acre-feet the average cost of development was \$6.75 per acre-foot of capacity.

The majority of reservoir dams are low earth fills, and slopes are protected against erosion by rock riprap or concrete pavements. For these comparatively short slopes both types of protection have given satisfaction.

Gate wells are now placed in the dam at the top of the inner slope. Locating them either at the upper or lower end of the outlet was found to be unsatisfactory and at times dangerous.

Outlet conduits are generally of stone or concrete and are often in cuts through the rim of the natural basin forming the bottom of the reservoir.

The aggregate capacity of reservoirs with decreed rights from the main river is now in excess of the normal available supply and further new projects of that type are not feasible. Storage development in the future should be along the line of flood-control reservoirs high up on the stream by which the flow of the stream below could be made to conform to actual current irrigation requirements,

rather than as a matter of necessity making irrigation practice conform to the flow of the stream and future as well as current needs. Were the Cache la Poudre Valley alone concerned this could be accomplished by a general pooling of interests as in the case of the exchange, but no doubt appropriators on the South Platte below would object strenuously to such a radical departure from custom unless they could be shown that no invasion of their rights would result.

The system of independent ownership of reservoirs and the resulting scale and rental of rights which may be used at any point affords a better distribution and a certain elasticity of supply which is on the whole very beneficial.

The amount of irrigation after September 15 in the Cache la Poudre Valley is negligible, and considering this valley alone, storage of the supply in the river should begin at that time.

Under the system of diversified crops common in the valley a relatively small amount of stored water is required. For practically the entire acreage under irrigation in 1916 and 1917 less than 25 per cent of the supply used was stored water.

The many farm reservoirs holding a few acre-feet play an important part in promoting a good use of water and their construction is recommended to secure a maximum benefit from a small flow, either constant or intermittent.

Absorption losses are relatively highest in small shallow reservoirs and the proportion decreases markedly with the increase in the volume of water stored.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
25 CENTS PER COPY

▽

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1027



Contribution from the Bureau of Chemistry
W. G. CAMPBELL, Acting Chief

Washington, D. C.

April 17, 1922

POISONOUS METALS ON SPRAYED FRUITS AND VEGETABLES.

By W. D. LYNCH, *Assistant Chemist*, C. C. McDONNELL, *Chief, Insecticide and Fungicide Laboratory*, and J. K. HAYWOOD, *Chief, Miscellaneous Division, Bureau of Chemistry*; A. L. QUAINANCE, *Entomologist in Charge, Fruit Investigations, Bureau of Entomology*; and M. B. WAITE, *Pathologist in Charge, Fruit-Disease Investigations, Bureau of Plant Industry*.¹

CONTENTS.

	Page.		Page.
Purpose of investigation.....	1	Results of experimental work.....	18
Results of previous investigations.....	1	Summary.....	58
Experimental work.....	16	Literature cited.....	58

PURPOSE OF INVESTIGATION.

In the spring of 1915 a cooperative study was undertaken in the United States Department of Agriculture to ascertain the amounts of arsenic, lead, and copper remaining on fruits and vegetables treated with poisonous sprays. The spraying was done under the direction of the Bureau of Entomology and the Bureau of Plant Industry, and the chemical work by the Bureau of Chemistry. The plan was to spray various fruit trees and vegetables according to accepted schedules, and also with excessive amounts of material to determine how much of the metals may be present under adverse conditions. In case the investigation showed that poisonous metals remained on the fruit in amounts which might prove injurious to the consumer, the results would constitute a basis for so changing or regulating the spraying schedules as to eliminate this danger.

RESULTS OF PREVIOUS INVESTIGATIONS.

Arsenical compounds first appeared as insecticides in the United States (63)² about 1860, when Paris green was used to check the

¹ Credit is due to John G. Fairchild and Wilbur A. Gersdorff for assistance in the analytical work reported in this paper.

² Figures in parentheses refer to Literature Cited, pp. 58 to 66.

ravages of the Colorado potato beetle. In 1872 Le Baron (70) suggested the application of Paris green to fruit trees to combat the spring cankerworm, but Lodeman (75) states that only a few of the most progressive orchardists adopted arsenical spraying against the codling moth until after the establishment of the State agricultural experiment stations resulting from the passage of the Hatch Act in 1887.

The question soon arose as to the possible danger to the consumer from the use of potatoes the vines of which had been treated with a poisonous compound, such as Paris green. One of the first investigators of this subject, Kedzie, in 1872 (64) and 1875 (65), concluded "that there is but very little danger of the potato tuber being poisoned so as to endanger the health of the consumer. Arsenic is equally deleterious to the vegetable as well as the animal system. If added in dangerous quantity to the plant, the plant dies, no potatoes are formed." McMurtrie (78) detected no arsenic in potatoes which had been subjected to applications of Paris green.

Lodeman (75) states that London purple was recommended as an insecticide in 1877. Cook (26), who sprayed apple trees on May 25 and June 20, 1880, at the rate of 1 pound of London purple to 100 gallons of water, reported that 100 blossom ends cut from the sprayed trees on August 19 showed no trace of arsenic. He proved also (27) that it took but a very small amount of the arsenites to kill potato beetles, currant slugs, and cabbage caterpillars, and discovered that the poison was retained on plants sheltered from rain for 10 to 20 days. He concluded that it was safe to use Paris green or London purple on trees the fruit from which would not be eaten for four or five weeks after the application.

Wheeler (132), in 1888, reported that it was safe in California, where rainless summers prevail, to spray vines with Paris green. When the vines were sprayed with 1 pound of Paris green to 16 gallons of water, "ten times as strong as the solution recommended for general use," Rising (114), the State analyst, found only traces of arsenic on the grapes and none in the wine made therefrom.

Objection was offered to the use of arsenicals, on the ground that they frequently caused more or less injury to the foliage. Gillette (58), however, found that "lime added to London purple or Paris green in water greatly lessens the injury that these poisons would otherwise do to foliage." Weed (129) recommended applying insecticides and fungicides together, and Gillette (58) showed that London purple can be used at least eight or ten times as strong without injury to foliage if applied in common Bordeaux mixture instead of in water. Gillette (59) stated, in 1891, that a mixture of 1 ounce of Paris green to 100 ounces of flour was the most effectual

remedy against the cabbage worm, applying "just enough to make a slight show of dust upon the leaves." These discoveries were quickly adopted in practice, and arsenicals were generally accepted as the best destroyers of external chewing insects.

The most important insecticides recommended, other than Paris green and London purple, were Scheele's green (113) in 1875, white arsenic plus lime (67) in 1891, and lead arsenate (40) in 1893. Until recently Paris green and lead arsenate have been the most extensively used, but calcium arsenate, now on the market, promises to become one of the leading arsenical insecticides.

The use of Bordeaux mixture originated in France near the city of Medoc. Viticulturists noticed that the vines near the highways, which had been sprinkled with a paste of milk of lime and copper sulphate to prevent thieving, did not suffer from mildew. Prof. Millardet, in 1882, attributed the beneficial action to copper, and later proposed a mixture of copper sulphate, lime, and water, since known as Bordeaux mixture (88) (89). The mixture was immediately accepted not only in France but in the United States, where F. Lamson Scribner (116) was probably the first to publish a formula for it as a result of the work in France. Its use has been extended to the prevention of so many plant diseases that to-day it is perhaps the most important fungicide.

When copper compounds were recommended as fungicides, the question arose as to whether or not spraying with them would leave a dangerous amount of copper on the grapes or in the wine.

Perrett (107) stated, in 1885, that there would be no danger of introducing copper into wine made from grapes sprayed with copper salts, because the hydrogen sulphid formed during fermentation would precipitate the copper as the insoluble sulphid. Quantin (111), in 1886, concluded that the reduction of the sulphate of copper by the ferments was sufficient to effect the total elimination of the copper in wine, but that aeration of the lees which inclosed the precipitated sulphid of copper should be avoided. Chuard (23) announced in 1887 that the copper was present in the must as copper malate, but that it was precipitated during fermentation as the sulphid and tartrate.

In October, 1885, Millardet and Gayon (90) obtained the following amounts of copper from vines that had been sprayed with Bordeaux mixture in July:

Fresh leaves (mg. per kgm.).....	19. 1-95. 5
Vine branches (mg. per kgm.).....	5. 8
Grape stalks (mg. per kgm.)	15. 0-18. 6
Marc's (mg. per kgm.).....	11. 1-21. 9
Musts (mg. per liter).....	1. 0- 2. 2
Wines (mg. per liter), from doubtful traces to less than.....	0. 1

The same authors, in 1886, report (56) the following amounts of copper at vintage from vines treated with various copper mixtures:

Grapes (mg. per kgm.).....	0.2-12.6
Must (mg. per liter).....	.0-11.8
Wine (mg. per liter).....	Fraction.

Examination of wines from different places in the southwest of France showed the presence of copper in the following amounts:

First wines:

White (mg. per liter), less than.....	0.01-1.0
Red (mg. per liter), less than.....	.01-2.8
Second wines (sweet wines) (mg. per liter).....	.01- .3
Press wine (mg. per liter).....	.05-1.7

Piquettes:

Normal (mg. per liter).....	.0-0.75
Sour (mg. per liter), less than.....	.01- 1.6

They attributed the absence of copper in wine to the action of the fermentation, the tannin and sulphur added to the wines before fermentation favoring the purification of the wine.

Crolas and Raulin (28) determined the amount of copper in the products of vines that had been treated six weeks to two months before vintage with different preparations containing copper, and found copper in the following amounts:

Grapes (mg. per kgm.).....	1.5- 3. 5
Mares (mg. per kgm.).....	.9 - 12. 8
Lees (mg. per kgm.).....	49.0-130. 0
Piquettes (mg. per liter).....	.0- .14
Wines (mg. per liter).....	.0- .36

Other investigators who have determined the amount of copper in wine (8) (16) (25) (29) (36) (41) (42) (45) (79) (104) (108) (118) (134) agree that the amount found in every instance was too small to be harmful.

C. L. Penny (105) reported, in 1889, 2.4 and 6.2 parts of copper per million for grapes that had been sprayed with Bordeaux mixture and 1 to 1.3 parts of copper per million for unsprayed grapes. These amounts were less than those found in some common articles of food. In 1890 (106) grapes so heavily sprayed that "either the appearance or the taste of the fruit would have condemned it on the market" were shown by Penny to contain about 47 parts of copper per million, "less than has been found in some articles of food admitted to be healthful, as beef liver."

In order to determine "whether there is any danger to be apprehended from eating grapes which have been sprayed with the Bordeaux mixture and other copper solutions," Galloway and Fairchild (47) gathered grapes from a plat which had been sprayed eight times with Bordeaux mixture. "The last spraying was made on these

vines July 30, and between that date and August 28, the date of harvest, only a few slight rains had fallen. The fruit showed the mixture plainly, more pronouncedly in fact than any treated grapes seen in the market. One kilogram of the clusters ($2\frac{1}{2}$ pounds), including the stems, which appeared to have the greater part of the copper, * * * yielded 0.005 gram (0.077 grain) of metallic copper," on analysis, about 0.035 grain of copper per pound of grapes.

In September, 1891, the Board of Health of New York City seized a quantity of grapes some of which had been heavily oversprayed with Bordeaux mixture (46). The following results of analysis of the most heavily sprayed bunches of grapes obtainable from the vineyards from which the grapes seized had come were reported (128):

(1) The amount of copper, estimated as metallic copper, found on the berries was very constant in the different samples, averaging $1/120$ grain for each pound of fruit (berries and stems).

(2) The amount of copper, estimated as metallic copper, found on the stems varied from $1/90$ to $1/14$ grain for each pound of fruit (berries and stems), and averaged $1/30$ grain.

(3) If the copper were on the berries in the form of sulphate of copper, each pound of berries would contain about $1/30$ grain of copper sulphate.

(4) As a matter of fact, copper, when found upon sprayed grapes in New York State, exists, not in the form of a sulphate, but in the form of a carbonate or hydroxid, both of which are not readily soluble and would, therefore, be even less dangerous than if present in the form of sulphate of copper. Most of the copper found was on the stems, and the rest of the copper was on the outside of the skin of the berries, which most people do not eat.

(5) The results obtained from estimating by chemical analysis the amount of copper on grapes, which were selected as being the worst sprayed that could be found, therefore, seem to justify the assertion that it is simply an absolute impossibility for a person to get enough copper from eating grapes to exert upon the health any injurious effect whatever.

According to Popenoe and Mason (109), "as much of the fruit (grapes) at the time of ripening showed a greenish-blue discoloration from the deposit of lime and copper, which had been applied twice since a rain had fallen, some persons feared that it might be poisonous." Analysis of those grapes showing the heaviest deposit gave for combined stems and berries 0.00188 per cent copper, or 0.52 grain of copper sulphate per pound of grapes. "A short time after this sample was taken a heavy shower washed off so much of the deposit that little of the remaining fruit was injured in appearance." Wheeler (131) found only slight traces of copper on grapes that had been sprayed with Bordeaux mixture. Alwood (6) reported no copper, or only traces, on grapes that had been sprayed with copper mixtures, and concluded "that these fungicides are perfectly harmless to consumers of the treated fruit." Maynard (84) reported that only 0.002 per cent of copper oxid was found on grapes which had been so heavily sprayed with Bordeaux as to be badly disfigured and that no

trace of copper could be found on grapes which had been properly sprayed with copper mixtures. From this it would seem "that even under the most careless use of the copper solutions, no injurious effects need be feared, and that when properly applied there will not be a trace of copper left upon the fruit at harvesting."

In 1892 the United States Department of Agriculture (9) published the following:

We take the ground that fruit sprayed with the copper compounds in accordance with the directions of the department is harmless. * * * For five years the copper compounds have been used by hundreds and thousands of fruit growers in every part of the United States, yet in all that time not a single authenticated case of poisoning, so far as we are aware, has been brought to light. * * * Accepting, then, 0.5 gram as the maximum amount of copper in any of the forms discussed that may with safety be daily absorbed, * * * that grapes sprayed intelligently rarely contain more than 5 milligrams (0.005 gram) of copper per kilogram, the average being from 2½ to 3 milligrams per kilogram, * * * an adult may eat from 300 to 500 pounds of sprayed grapes per day without fear of ill effects from the copper. This shows how ridiculously absurd are the statements that fruits properly sprayed with the Bordeaux mixture or any other copper compound are poisonous. * * *

According to numerous analyses, wheat may contain from 4 to 10 milligrams of copper per kilogram. * * * We do not see how any foreign country can logically object to American fruits on the ground that they contain copper without also objecting to wheat.

Wheat, however, does not contain anything like as much copper as some other foods and drinks. Beef liver and sheep liver, according to reliable and repeated analyses, contain, respectively, from 56 to 58 and 35 to 41 milligrams of metallic copper per kilogram of fresh substance, while in chocolate the enormous amount of 125 milligrams to the kilogram has been found. In conclusion, it is only necessary to call attention to one other matter to show how unjust and discriminating it would be to condemn American fruits on the ground that they contain copper in unwholesome quantities. Analyses of vegetables that have been regreened by the copper process show that they may contain from two to sixty times as much of the metal as sprayed grapes.

In this connection the presence of copper reported in various foodstuffs in the following amounts is of interest:

From 4 to 10 milligrams per kilogram in wheat (43); 56 to 58 milligrams per kilogram in beef liver (105); about 40 milligrams per kilogram in sheep liver (35) (100); from 5.6 to 20.8 (44) and from 5 to 125 (31) milligrams per kilogram in chocolate; from 11.2 to 29.2 (44) and from 9 to 40 (31) milligrams per kilogram in cocoa; from 35 to 250 milligrams per kilogram in cocoa shells (31). Instances are cited (77) where as much as 270 milligrams of copper per kilo was found in French peas that had been subjected to the regreening process. Tschirch stated (127) that copper is widely distributed in plant and animal bodies, always, however, in small amounts; that it enters the animal bodies through food and dust; but that the presence of copper in the bodies of man and other higher animals is not to be considered as "normal." He stated further that plants absorb only small amounts of copper from the ground; that no danger to health need be expected from the consumption of wine from sprayed grapes or of potatoes from sprayed fields, and that even the must of coppered grapes may be eaten and the skins (containing 0.006 gram of copper per kilo) used as fodder; that spraying with copper against fungous diseases might be continued without fear of harm; that only very small quantities of the copper compounds entering the mouth

are taken up by the blood, and poisoning can occur only if the necessary quantity enters the circulation; and that to forbid copper in foods and drinks is to forbid those plants which take it up from the ground, and also to designate the use of bread and chocolate as dangerous to the health.

Lehmann reported the following amounts of copper per kilogram in various plant and animal substances: In wheat, 7.5 milligrams; in cherries, 1.5 milligrams; in pears, 0.5 milligram; and in beef liver, from 6.4 to 59 milligrams (71) (73). He stated (72) that the species of the plant had far less influence than the quantity of the copper in the soil on the amount taken up by the plant.

In 1891 objections to the use of American apples because of the presence on them of arsenic were made in certain British journals. However, Maynard (85), Munson (97), and Fletcher (38) proved that the objection had no basis in fact, and later (10) (103) (126) it became apparent that such objections to sprayed fruit in England were neither very general nor very deep-seated.

Table 1 shows the amount of arsenic and copper found by R. C. Kedzie (66) on fruit sprayed with Bordeaux mixture and London purple in 1892 and 1893.

TABLE 1.—*Arsenic and copper on fruit sprayed in 1892 and 1893 with Bordeaux mixture and London purple (Kedzie).*

Fruit.	Date sprayed.	Date picked.	Spray used.	As ₂ O ₃ .	CuSO ₄ .5H ₂ O.
	1892.	1892.		<i>Grains per pound.</i>	
Strawberries.....	June 18, 23....	June 24	6-4-32 Bordeaux, 1 pound London purple, 200 gallons water.	0.0440	4.870
Do.....	do.....	do.....	2-1-32 Bordeaux, 1 pound London purple, 200 gallons water.	.0298	1.821
Red cherries.....	June 18, 30....	July 6	6-4-32 Bordeaux, 1 pound London purple, 200 gallons water.	.0882	.390
Do.....	do.....	do.....	2-1-32 Bordeaux, 1 pound London purple, 200 gallons water.	.0250	.252
White cherries.....	June 30.....	July 1	6-4-32 Bordeaux, 1 pound London purple, 200 gallons water.	.1210	.....
Red currants.....	May 25, June 7, 18, 30....	July 8	London purple.....	.0503	.....
Raspberries.....	June 6, 28, July 8....	July 20	2-1-32 Bordeaux, 1 pound London purple, 200 gallons water.	.0098	.023
Gooseberries.....	June 18, 29, July 8, 22....	Aug. 2	6-4-32 Bordeaux, 1 pound London purple, 200 gallons water.	.0233	.601
Do.....	do.....	do.....	do.....	.0372	.362
Pears.....	June 15, July 7, 21, Aug. 7....	Sept. 6	do.....	.0088	.0738
Do.....	1893. May 15, June 12, July 10....	.....	No London purple, 2-2-32 Bordeaux.	.....	.100
Russian cherries...	May 14, June 10, 18, July 15....	.....	First 3 dates, 2-2-32 Bordeaux; last date, "eauceleste."	.....	.147
Plums.....	do.....	do.....	do.....	.....	.200

The skins from 1 pound of the sprayed pears gave 0.106 grain and the flesh gave 0.071 grain of copper sulphate, "showing that while most of the copper salt adheres to the surface, a portion finds its way into the body of the fruits."

In 1893 Davis (30) reported the determinations of arsenic on celery that had been sprayed with Paris green at the rate of 1 pound to 175 gallons of water. The results, obtained on the celery washed without separating the stalks and prepared as for market, were as follows: Sprayed once, 0.0244 grain of arsenious oxid per pound of celery; sprayed twice, 0.0368 grain of arsenious oxid per pound of celery.

In 1893 Beach reported (12) the presence of from 0.00042 to 0.001 per cent of copper in celery that had been sprayed with Bordeaux or ammoniacal copper carbonate solution, and 0.00081 per cent in unsprayed celery, concluding that "these investigations show that when this sprayed celery was stripped and ready for market the sprayed plants were no more poisonous than the unsprayed."

In 1894 Kinney (68) stated that the skins and stems of pears which had been sprayed five times with Bordeaux mixture (6 pounds of copper sulphate, 4 pounds of lime, and 22 gallons of water), and upon which the spray was still visible at harvest contained only 0.016 grain of copper oxid per pear, for which reason no serious objection to this treatment could be raised from a hygienic standpoint.

In 1894 Garman reported (49) that the skins and ends of six apples from a tree that had been sprayed once with London purple and five times with Paris green at the rate of 1 pound to 160 gallons of water showed on analysis no arsenic and only an unweighable amount of copper. The flesh and cores of these apples gave no reaction for arsenic or copper. He reported also (50) that cured tobacco which had been sprayed with arsenites, at the rate of 1 pound to 160 gallons of water, gave on analysis 0.077 grain of arsenious oxid and 0.042 grain of copper oxid per pound with one spraying with Paris green; 0.133, 0.259, and 0.329 grain of arsenious oxid and 0.126, 0.210, and 0.322 grain of copper oxid per pound with two sprayings with Paris green; and 0.245 grain of arsenious oxid per pound with two sprayings with London purple. Later (1904) this author stated (51) that arsenites such as Paris green can be used on cabbage without leaving a trace sufficient for recognition by the chemist. In 1901, cabbages which had been sprayed with Paris green or lead arsenate showed on analysis "traces of poison present." In 1902, and again in 1903, sprayed cabbages were analyzed, but the chemist "was unable to find a trace of poison present."

In 1897 Teyxeira (123) found from 20 to 50 milligrams of copper in 1 kilogram of juice from tomatoes that had been sprayed with copper sulphate, and none after treatment with Bordeaux, unless the skin was cracked. He stated that the copper sulphate penetrates the skin into the flesh, but that the copper-lime mixture does not.

In 1898 Hoffmann reported (62) the presence of from 0.0046 to 0.0128 gram of copper per liter in wines, but failed to give the history of the samples. Later he reported 0.00096 and 0.0058 gram of copper per liter in wine, 0.0028 and 0.0056 gram of copper per liter in must, 0.0027 and 0.0045 gram of copper per liter in grape-skin wine, and 0.053 gram of copper per 100 grams in the grape skins.

Selby found (117) 0.0004 gram of copper per 100 grams of grapes to be the maximum amount on the samples he examined. To show that sprayed grapes can be safely used for making wine he cites Krüger (69), "that in the different musts different amounts of copper, at the beginning of fermentation, or just before the beginning, enter into an insoluble and consequently an inert (copper) compound, in consequence of the presence of greater or less amounts of organic acids. From this condition it is likely that the copper of the must, arising from the spraying of the grapes, is without any importance for the wine."

Gibbs and James (57) reported that 292 of 352 samples of wine examined contained no arsenic, 58 contained from a trace to 1 part in 8,000,000, 1 contained 1 part in 5,000,000, and another 1 part in 2,500,000. They stated also that of 200 samples of wine examined by C. S. Ash the three highest in arsenic contained 1 part in 6,000,000, 1 part in 8,000,000, and 1 part in 14,000,000. "The most probable sources of the major part of that found are arsenical sprays when used upon the vines, sulphur burned for the purpose of sulphuring the wines and receptacles, and perhaps to some extent the lead shot used in cleaning the bottles." A sample of sulphur from a California winery was found to contain arsenic in the proportion of 1 part in 5,000. It is not stated whether these wines were the product of sprayed vines.

In 1906 Roger Marès (82) reported that he found no trace of arsenic in wine from a vine treated a month before grape gathering with a copper-arsenical mixture, and he accordingly continued to recommend this combined mixture as a spray for the vines in Algiers. The same year Von der Heide (61) reported the results shown in Table 2 on products of vines that had been sprayed with lead arsenate.

TABLE 2.—*Metals on products of vines sprayed with lead arsenate (Von der Heide).*

	Arsenic.	Lead.	Copper.
Grapes (bunches) (milligrams per 100 grams).....	0.3	0.7	.....
Grapes (individual) (milligrams per 100 grams).....	.2	.3	.....
Stems (milligrams per 100 grams).....	7.1	10.6	.....
Leaves (milligrams per 100 grams).....	16.0	48.0	27
Grape skins (milligrams per 100 grams).....	.7	1.4	.....
Must (milligrams per 100 grams).....	.6	.8	.....
Fall wine (milligrams per 100 grams).....	.3	.8	.....
Spring wine (milligrams per 100 grams).....	.2	.6	.....
Wet lees (milligrams per 100 grams).....	.1	.2	.....
Dry lees (milligrams per 100 grams).....	3.0	4.8	.....
	12.9	20.7	.....

The German Imperial Health Commission was opposed to the use of lead arsenate in the spraying of grapes because arsenic and lead were found in the wine.

In 1907 Szameitat (121) (122) reported the following results of analyses of musts, wines, and grapes from vines sprayed with arsenic compounds: From a trace to 0.9 milligram of arsenic in 300 grams of grapes; none to 0.14 milligram of arsenic in 300 cubic centimeters of must; none or only a trace in 300 cubic centimeters of wine. Of 38 samples of German wine examined, 24 showed small amounts of arsenic, the largest amount being 0.05 milligram in 100 cubic centimeters of wine. The source of arsenic was not identified.

The use of arsenic compounds for the destruction of insects that devastated vines having become more or less general in central France, in spite of the fact that the French ordinance of 1846 prohibited the use of arsenic for the destruction of insects, the question arose as to the danger of such use.

In 1907 Bertin-Sans and Ros (14), who were among the first in France to publish an answer to this question, found less than 0.001 milligram of arsenic in 145 grams of unripe grapes gathered one month after spraying with sodium arsenate, and 0.002, 0.001, 0.030, and 0.040 milligram of arsenic per liter in wine from arsenical treated vines. These investigators stated that as sheep and cows were not admitted to the sprayed vines and were not fed the sprayed foliage until after harvest there was no danger to these animals, but that rabbits and snails might be poisoned by eating sprayed foliage, and, since snails can tolerate a fairly large amount of arsenic, persons should refrain from eating them during the spraying season. As lead is a cumulative poison, it was considered more prudent to use arsenicals other than lead arsenate, although no data existed to show that there was danger in the use of lead arsenate as an insecticide. Bertin-Sans and Ros believed that the chief danger in the use of arsenicals arose from mistakes due to carelessness and that if suitable regulations were enforced no danger was to be feared. Since the ordinance of 1846 was a dead letter, it seemed to them much better to have the arsenicals handled under definite regulations. In 1908 (15) they stated that as they had found only traces of arsenic in wine from vines sprayed with arsenicals, there was no ground for the fear that the arsenic would pass into the wine if the vines had been sprayed before the grapes were in bloom.

In 1909 Truelle (125) (126) concluded that the advantages of arsenical spraying were so great that its use under regulation should be authorized in France.

Cazeneuve (21), thinking that the use of arsenical insecticides was a serious menace to the public health, asked (1908) for the strict enforcement of the ordinance of 1846. Riche (112) and Gautier (52),

on the other hand, believed that the use of arsenicals, with the exception of lead arsenate, should be permitted in agriculture, but only under proper regulation.

In 1909, a committee appointed by the Academy of Medicine (1) (21) (112) to study this question recommended (96) the strict enforcement of the ordinance, thus causing a very lively discussion. Weiss (130), believing that the committee did not have sufficient evidence to substantiate its recommendation, proposed a medical investigation, this proposal being adopted (2) and sent to the minister of the interior as the advice of the academy. A year later the academy asked (32) that a new investigation, essentially medical, be carried on for two years, and, to avoid accidents, recommended strict regulations in the use of arsenicals and the complete exclusion of lead arsenate. The direction of the investigation was to be intrusted to the councils of hygiene and the sanitary commissions of each department, after consultation with the professors of agriculture (33). In 1911, dissatisfied with the lack of enforcement of its suggestions, the academy decided (34) to recall to the public powers the conditions they had recommended as to the use of arsenicals in agriculture. Malvy, undersecretary of state, stated (80) that since the investigation conducted by the minister of the interior had disclosed no accident, either among the workers who handled the arsenicals or among the consumers, to prohibit the use of lead arsenate would be to impose useless annoyances on merchants and viticulturists. In 1913 the minister of the interior submitted to the Academy of Medicine a draft of a decree carrying modifications of the ordinance of 1846, permitting the use of insoluble arsenicals in agriculture (3).

After much discussion (5) (22) (53) (54) (76), articles 9 and 10 of the draft, authorizing the use of arsenicals in agriculture under specified regulations, were adopted by the academy (4) (5); with the recommendation that the order of the minister of agriculture dealing with the precautions to be taken in their use should apply to all arsenicals and not merely to lead arsenate, and article 11, which prohibited the sale and use of soluble arsenic salts, was amended to permit their sale when "denatured" (5). The academy also voted (5) that the public powers be requested to take every means to inform the public of these regulations and to impose penalties for their infraction, and that the Government be requested to encourage researches to find substitutes for arsenicals. The French decree authorizing the use of insoluble arsenicals in agriculture, under regulation (81), and the minister of agriculture's instructions for the sale and use of these arsenical compounds were published in 1916 (86). The sale and use of *soluble* arsenicals as insecticides were prohibited.

Breteau (17) analyzed 15 samples of wine from vines sprayed with arsenicals, finding from none to 0.04 milligram of arsenic per liter in

12 of the samples and 0.1, 0.1, and 0.2 milligram of arsenic per liter in the other three. He attributed the higher content of arsenic in the last three samples to the fact that the wines had been sulphured. If, as held by Gautier and Clausmann (55), a normal wine contains about 0.01 milligram of arsenic, he felt that the arsenical treatment of vines will introduce into the wine less than 0.03 milligram of arsenic per liter. Mestrezat (87) considered that the only danger from the use in viticulture of arsenical insecticides occurs when they are placed near other substances which resemble them so closely as to be easily mistaken for them. In 1906 Forbes (39) reported 36.6 and 32.9 parts of arsenious oxid per million in peelings of apples sprayed the preceding day with lead arsenate and 40.1 parts of arsenious oxid per million in peelings of apples gathered two months after being sprayed heavily with lead arsenate. He considered that lead arsenate could be substituted for the more common insecticide sprays if discretion were exercised in its use. In 1910 Günther (60) reported the results given in Table 3 on fruits that had been sprayed once with a mixture containing 300 grams of sodium arsenite and 425 grams of lead acetate per 100 liters.

TABLE 3.—*Residue on fruits sprayed once with mixture containing 300 grams of sodium arsenite and 425 grams of lead acetate per 100 liters (Günther).*

	Days elapsed after spraying.	Arsenic.	Lead.
		Milligrams per 100 grams.	
Gooseberries.....	39	1.000	2.16
Currants.....	39	7.140	16.70
Pears.....	80-106	.129	
Apples.....	80-106	.074	Trace.
Do.....	50-106	.057	0.017

He reported the results given in Table 4 on fruits dusted once with a mixture consisting of 2 parts of freshly slaked lime, 4 parts of sulphur, and 1 part of Paris green.

TABLE 4.—*Residue on fruits dusted once with a mixture consisting of 2 parts of freshly slaked lime, 4 parts of sulphur, and 1 part of Paris green (Günther).*

	Days elapsed after dusting.	Arsenic.	Copper.
		Milligrams per 100 grams.	
Gooseberries.....	39	0.8300	0.560
Do.....	39	2.1200	.930
Currants.....	39	1.6100	
Do.....	39	1.5300	.870
Pears.....	80-106	.0720	.240
Apples.....	80-106	.0420	.067
Do.....	80-106	.0084	.095
Do.....	80-106	.0420	.011
Sweet cherries.....	24	.2000	.160
Sour cherries.....	24	.3200	.250
Plums.....	24	.5000	Trace.

In 1910 Bedini (13) reported from 0.2 to 0.4 milligram of arsenious oxid per kilogram in the skins of pears that had been sprayed with arsenate of iron, and only a trace of arsenic in the pulp. The same year Porchet (110) reported that pears sprayed with lead arsenate contained as much as 0.3 milligram of arsenious oxid per kilogram in both the pulp and the skin; that the skins of unsprayed pears contained 0.035 milligram of arsenious oxid per kilogram of fruit; that sprayed grapes contained traces of arsenic, apparently the same in the interior as on the exterior of the fruit, the highest amount obtained being 0.2 milligram per kilogram of grapes; and that the traces of arsenic passed from the grapes into the must, but that the arsenic was precipitated as sulphid during the fermentation. Chuard (24) also found that the arsenic in the must was precipitated as sulphid during the fermentation.

Fetel (37), in 1910, reported that 10 samples of grapes bought on the market in Algeria on August 8 and 25, September 1 and 19, and October 3 contained an average of 0.038 milligram of arsenic per kilogram, while unsprayed grapes, collected on August 8 and September 1 and 8, contained no arsenic. Grapes sprayed twice before blossoming, with a Bordeaux-sodium-arsenate mixture, and gathered on August 10 and 25 and September 5 and 22, contained, respectively, 0.185, 0.083, 0.074, and 0.074 milligram of arsenic per kilogram. Grapes sprayed twice before flowering with arsenious acid and on July 24 with Bordeaux-arsenious-acid mixtures, and gathered on July 24 before and after this last spraying, on August 22, and on September 15, contained, respectively, 0.056, 0.467, 0.149, and 0.112 milligram of arsenic per kilogram.

In 1909 and 1910 Brioux and Griffon (18) found 0.001, 0.001, and 0.004 milligram of arsenic per kilogram in three lots of pears that had been sprayed with a Bordeaux-lead-arsenate mixture. They also reported that, although apples which had been sprayed with lead arsenate on June 8 and June 22, 1910, contained when examined in July 1.3 milligrams of arsenic and 14.2 milligrams of lead per kilogram, yet in September, at harvest time, the apples and the cider contained no lead and only traces of arsenic.

Moreau and Vinet (92), in 1910, reported that grapes sprayed with lead arsenate on May 27 and June 6 contained, respectively, on June 22 and September 14, about 2 and 0.28 milligrams of lead arsenate per bunch, and that 165 grams of moist lees contained 1.38 milligrams of lead arsenate, but that the wines contained no lead or arsenic. They found (93) that only 1 per cent of the lead arsenate which they had applied on May 31 was retained by the grapes, 0.58 milligram per bunch, and that with the development of the grapes a second spraying was necessary on June 14 to control the first generation of the cochylis larva. They also found that a spraying on August 6 to control the

second generation of this insect adhered mostly to the stems. They concluded from other experiments (94) that, since grapes sprayed twice with lead arsenate before flowering, on May 31 and June 14, showed no lead or arsenic at harvest time, October 15, there would be no danger in consuming grapes sprayed so early, but that, since grapes sprayed after the flowering period, on August 6, showed 0.40 milligram of lead arsenate per 100 grams of grapes at harvest time, October 27, there might be danger in consuming grapes sprayed so late in the season. They reported further (95) that wines from vines treated before the flowering period with lead arsenate could be consumed without danger, since only faint traces of lead and arsenic were found in wines from such vines and that the lead and arsenic were eliminated during the process of the making of the wine, being found principally in the marc and in small amounts in the lees.

In 1911 Ampola and Tommasi (7) stated that foodstuffs derived from plants treated with arsenical compounds always contain arsenic, usually in traces, but sometimes as much as 2 milligrams or even more per kilogram in fruits and 1.5 milligrams per liter in wine, amounts greater than that allowed by the Royal Commission on Arsenical Poisoning in England (11) (115).

In 1912 Muttelet and Touplain (99) reported that the grapes, marcs, wines, piquettes, and lees which came from vines treated with lead arsenate contained about the same amount of arsenic as was found in the products from vines not treated, that the wines and piquettes contained no lead, but that the lees in certain cases contained an appreciable quantity of lead, in which cases there was danger in the consumption of wine or piquette before the deposition of the lees, and that grapes sometimes retained on their surface a quantity of lead which rendered dangerous their consumption in a natural state. The same year Carles and Barthe (20) reported that the wines from vines sprayed before the formation of the fruit with excess of lead arsenate contained only negligible traces of arsenic and lead and that those from vines normally treated with lead arsenate contained neither arsenic nor lead, but that the lees contained 0.0028 and 0.0004 gram of arsenic per liter and traces of lead. According to Mathieu (83), unsprayed grapes and wines made from them contain only traces of arsenic, grapes from vines sprayed with arsenicals before flowering contain not more than 0.05 milligram of arsenic per kilogram, even in a dry year, red wine made from grapes treated with arsenicals in a year of abundant rain contains only a little more arsenic than wine made from unsprayed grapes, the amount being less than 0.06 milligram per liter, and part of the arsenic in the grapes remains in the marc in making red wines, which wines, however, should not contain more than 0.05 milligram per liter. In 1914 Garino (48) stated that the amounts of arsenic met in analyses of

wines from grapes subjected to cupro-arsenical treatment are very small, being less than the minimum therapeutic dose of 5 milligrams, and therefore need cause no alarm.

In 1913 Spallino (120) found in three samples of snuff 0.16, 0.40, and 0.34 milligram of arsenic per 100 grams of dried snuff, and in four samples of smoking tobacco 0.08, 1.02, 0.30, and 0.64 milligrams of arsenic per 100 grams of dry tobacco.

Sonntag (119), in 1914, concluded from the results he obtained on ripe fruits and leaves treated in 1907 and 1908 with arsenical mixtures that the arsenical sprays or dusts applied to fruit trees and bushes adhere to the fruits and are retained by them for a long time, in many cases even until the ripening of the fruit.

O'Gara (101) stated that the skin of apples sprayed with lead arsenate may occasionally absorb some arsenic. In such cases the skin is likely to develop red or black spots. Analysis of such spotted apple skins showed the presence of fractions of a milligram of arsenic. Woods (133) reported that apples sprayed with lead arsenate during the first week in August, 1913, carried upon their surface, about two months after spraying, from one-eighth to one-third milligram of lead arsenate per apple. He concludes that "midsummer spraying with lead arsenate is an effective way of combating the brown-tail moth," and "the amount of arsenic or of lead that will remain at harvest upon the apples that are sprayed in midsummer with arsenate of lead is so slight as to have no practical bearing."

In 1916 Trofimenko and Obiedoff (124) reported that grapes treated with wet arsenical mixtures under conditions most favorable for the continuance of the arsenical salts, both on the grapes and in the must, yielded unobjectionable wines. No arsenic was found in white wine and only 0.0002 gram of arsenious oxid per liter in red wine. The lees might be used for extracting the tartar, washing being enough to remove the arsenates. Muttelet (98) stated that the wine and piquette from vines treated with copper sulphate and lead arsenate, even after the formation of the grapes, contained no lead or copper, and no more than traces of arsenic. The pomace wine contained no lead, traces of copper, and 5 milligrams of arsenic per hectoliter. The lees contained 500 milligrams of lead, 10 milligrams of arsenic, and traces of copper per liter. The air-dried marc contained 200 milligrams of lead, 0.1 milligram of arsenic, and traces of copper per kilogram.

Liberi, Cusmano, Marsiglia, and Zay (74) found copper in the fruit of tomatoes in amounts varying from 0.14 to 2.10 milligrams per kilogram of juice and pulp, and from 3.8 to 19.5 milligrams per kilogram of dry matter. The soils upon which the tomatoes were grown contained copper up to 110 milligrams per kilogram. These investigators stated that the spraying with copper mixtures had no

effect upon the copper content of the tomatoes. It appeared that the copper found in the tomatoes came from the soil, whence the plants assimilated it in different proportions, according to the nature of the soil or under the influence of other factors.

In 1917 Carles (19) stated that copper occurs in small amounts in agricultural products and in larger amounts in calf liver and beef liver. O'Kane, Hadley, and Osgood (102) reported the following amounts of arsenic (calculated as As_2O_3) on fruits and vegetables that had been sprayed with dry lead arsenate equivalent to 3 pounds of lead arsenate paste to 50 gallons of water: Apples picked at intervals ranging from 3 to 91 days after spraying, 0.08 to 0.77 milligram per apple when picked carefully, 0.02 to 0.50 milligram when picked in the ordinary way, 0.10 to 0.21 milligram when picked with cotton gloves, and 0.08 to 0.18 milligram when picked with cotton gloves and wiped; strawberries picked 2 and 6 days after spraying, from 8.6 to 34.2 milligrams per quart; currants picked 3, 6, and 8 days after spraying, from 6.8 to 10.2 milligrams per quart; blackberries picked on the day they were sprayed, from 3.8 to 11.2 milligrams per quart; cabbage gathered 2 and 8 days after spraying, from 43.5 to 51.4 milligrams per head; and lettuce gathered 1 and 6 days after spraying, from 1.6 to 10.6 milligrams per head. The maximum amount of lead arsenate spray that would adhere to an apple, when sprayed directly, was found to be an amount equivalent to 4 milligrams of arsenious oxid. Such fruit gave evidence of spray material on its surface.

EXPERIMENTAL WORK.

The investigation conducted by the United States Department of Agriculture included experiments on peaches, cherries, plums, apples, pears, grapes, cranberries, tomatoes, celery, and cucumbers. The spraying schedules are shown in Tables 5 to 14.

METHODS OF ANALYSIS.

The following methods of analysis were employed:

Of the whole fruit and pulp, dry 200 to 300 grams of sample on the steam bath in glass dishes, and report loss as "loss on drying." (For the determinations on the skins, use parings from 4 apples; for the calyx and stem end determinations, use 12 apples and corresponding amounts in the case of other fruits.) Transfer the dried residues to casseroles and add 100 to 200 cc. nitric acid. Heat the mixture, if necessary, to start action, and when violent action is over cautiously add 20 cc. sulphuric acid. Heat on hot plate, removing at intervals to add small amounts (3 to 5 cc.) of nitric acid (do not allow the solution to become black), and when the oxidation is complete evaporate until sulphuric acid fumes are given off. Cool, dilute with water, and again evaporate to sulphuric acid fumes. Cool, dilute with about 100 cc. of 50 per cent alcohol, and let stand over night. Filter and wash with 80 per cent alcohol. Save sulphate precipitate for lead determination. The copper and arsenic are determined in the filtrate. Evaporate the filtrate to small volume on steam bath to remove alcohol. Make to volume.

Arsenic.—Determine arsenic in an aliquot by the Gutzeit method (Bur. Chem. Circ. 102), modified as follows: The aliquot should contain less than 0.08 mg. arsenic. Dilute to 50 cc. Add strong sulphuric acid so as to have 10 cc. present. Add 1 gram sodium chlorid to the aliquot in a small Erlenmeyer flask, heat on steam bath to about 90° C., then add 1 cc. of a stannous chlorid solution containing 0.5 gram dissolved in hydrochloric acid, and leave on steam bath for about 5 minutes (temperature near 90° C.). Remove from steam bath, transfer to the 4-ounce generating bottle, dilute to 100 cc., and cool to room temperature. This generating bottle is connected by a rubber stopper with an upright tube 8 cm. long, 1 cm. diameter, containing lead acetate paper. This tube is connected by a rubber stopper with a similar tube containing cotton moistened with 5 per cent lead acetate solution. Connected by a rubber stopper with this tube is a capillary tube 3 mm. in diameter, 12 cm. in length, carrying the strip of mercuric bromid paper. Prepare these strips as follows: Cut heavy, close-textured drafting paper into strips 2 mm. by 12 cm.; then soak them for an hour in 5 per cent alcoholic mercuric bromid solution, take out, rapidly squeeze off excess of solution, separate on glass rods, and allow to dry. Place three pieces of stick zinc (about 10 grams) in the generating bottle and join it immediately to the apparatus tubes. Allow the determination to run for 1½ hours, keeping the temperature down to room temperature by placing the bottle in cool water. From standards plot a curve showing milligrams of arsenic to millimeters in length. As high as 0.08 milligram of arsenic can be read on a paper. Determine the larger quantities of arsenic by passing the arsine into a mercuric chlorid solution and either weigh the mercurous chlorid or titrate the arsenious oxid. (Bur. Chem. Circ. 102, p. 5.)

Copper.—Introduce an aliquot into a 100 cc. Erlenmeyer flask. Neutralize the acid with ammonia, add 2 to 3 cc. hydrochloric acid for every 50 cc. of solution, and saturate the solution with hydrogen sulphid. Stopper flask and let stand over night. Filter off the copper sulphid and wash with hydrogen sulphid water. Place the filter paper containing the copper sulphid in a 50 cc. casserole, burn off the paper, dissolve residue in 5 cc. (1:1) nitric acid, evaporate to dryness, add water and 1 drop ammonia, make faintly acid with acetic acid, and add a few drops of a 2 per cent potassium ferrocyanide solution. Compare with standards.

Lead.—Dissolve the sulphate precipitate, previously referred to, in hot 10 per cent ammonium acetate solution, add 2 cc. (0.1 per cent solution) gum arabic, and make to volume with hydrogen sulphid water in 50 cc. (or 100 cc.) Nessler tubes. Compare the tubes thus prepared with standards made up similarly with gum arabic, ammonium acetate, known amounts of lead, and hydrogen sulphid water.

Where copper alone is to be determined, heat the dried sample cautiously over a Bunsen burner and finally ash at the mouth of the electric-muffle furnace. Add 5 cc. (1:1) nitric acid to the ash, evaporate almost to dryness on steam bath, dilute, and make alkaline with ammonia. Filter off precipitate and wash. Dissolve precipitate, reprecipitate with ammonia, and wash. Evaporate the united filtrates to dryness, add water and one drop ammonia, make slightly acid with acetic acid, and add a few drops 2 per cent potassium ferrocyanide solution. Compare with standards.

The presence of between 0.02 and 0.24 milligram of copper can be determined by this method. Larger amounts may be determined by taking an aliquot, by comparing in ammoniacal solutions, or by electrolysis.

The presence of from 0.02 to 0.24 milligram of lead can be read in the 50 cubic centimeter Nessler tubes, larger amounts by using 100 cubic centimeter Nessler tubes or by taking a smaller aliquot.

The whole and pulp of apples were fumed in 7-inch casseroles and the skins were fumed in 5-inch casseroles, all being transferred to 4-inch casseroles before final fuming. Casseroles were covered until final fuming.

RESULTS OF EXPERIMENTAL WORK.

The results of the chemical analyses appear in Tables 5 to 15, inclusive.

TABLE 5.—*Arsenic and lead remaining on sprayed peaches at picking time.*

Sample No.	Spray material used. ¹	Date sprayed.	Determinations made on.	Arsenic(As).		Lead (Pb).		Arsenic.	Lead.	Loss on drying.	Average weight of peach.
				Original fruit.	Dried fruit.	Original fruit.	Dried fruit.				
		1915.		<i>Parts per million.</i>				<i>Mg. per peach.</i>		<i>P.ct.</i>	<i>Gr.</i>
23196 ²	48 lbs. hydrated lime, 2 lbs. lead arsenate (powder).	May 9 ³	Whole ⁴	0.13	0.90	0.40	2.7	0.014	0.042	85.3	105.3
			Pulp.....	.06	.40	.20	1.4	.005	.016	85.8	
			Skin.....	.42	2.60	1.20	7.3	.009	.026	83.6	
	2 lbs. lead arsenate (powder), 32 lbs. hydrated lime, 16 lbs. sulphur.	May 26	Whole ⁴	.18	1.30	.40	2.8	.018	.040	85.7	100.5
			Pulp.....	.08	.60	.10	.7	.006	.008	86.0	
			Skin.....	.61	4.00	1.60	10.4	.012	.032	84.6	
23197 ²	16 lbs. sulphur, 34 lbs. hydrated lime.	July 10	Whole ⁴	.18	1.30	.40	2.8	.018	.040	85.7	100.5
			Pulp.....	.08	.60	.10	.7	.006	.008	86.0	
			Skin.....	.61	4.00	1.60	10.4	.012	.032	84.6	
23198 ²	32 lbs. sulphur, 4 lbs. lead arsenate (powder), 14 lbs. hydrated lime.	May 26	Whole ⁴	.25	1.80	.80	5.7	.024	.076	85.9	95.2
			Pulp.....	.08	.60	.20	1.4	.006	.015	86.1	
			Skin.....	.90	6.10	3.00	20.4	.018	.061	85.3	
23199 ²	32 lbs. sulphur, 18 lbs. hydrated lime.	July 10	Whole ⁴	.25	1.80	.80	5.7	.024	.076	85.9	95.2
			Pulp.....	.08	.60	.20	1.4	.006	.015	86.1	
			Skin.....	.90	6.10	3.00	20.4	.018	.061	85.3	
23200 ²	44 lbs. hydrated lime, 6 lbs. lead arsenate (powder).	May 9 ³	Whole ⁴	.25	1.80	.80	5.7	.024	.076	85.9	95.2
			Pulp.....	.08	.60	.20	1.4	.006	.015	86.1	
			Skin.....	.90	6.10	3.00	20.4	.018	.061	85.3	
23201 ²	44 lbs. sulphur, 6 lbs. lead arsenate (powder).	May 26	Whole ⁴	.25	1.80	.80	5.7	.024	.076	85.9	95.2
			Pulp.....	.08	.60	.20	1.4	.006	.015	86.1	
			Skin.....	.90	6.10	3.00	20.4	.018	.061	85.3	
23202 ²	Sulphur alone.....	July 10	Whole ⁴	.25	1.80	.80	5.7	.024	.076	85.9	95.2
			Pulp.....	.08	.60	.20	1.4	.006	.015	86.1	
			Skin.....	.90	6.10	3.00	20.4	.018	.061	85.3	
23203 ²	11 lb. lead arsenate (powder), 50 galls. water.	May 9 ³	Whole ⁴	.20	1.50	.30	2.2	.020	.029	86.2	98.0
			Pulp.....	.08	.60	.10	.8	.007	.008	86.7	
			Skin.....	.66	4.20	1.10	7.0	.013	.021	84.2	
23204 ²	50 galls. self-boiled lime-sulphur, 1 lb. lead arsenate (powder).	May 26	Whole ⁴	.20	1.50	.30	2.2	.020	.029	86.2	98.0
			Pulp.....	.08	.60	.10	.8	.007	.008	86.7	
			Skin.....	.66	4.20	1.10	7.0	.013	.021	84.2	
23205 ²	Self-boiled lime-sulphur.	July 10	Whole ⁴	.20	1.50	.30	2.2	.020	.029	86.2	98.0
			Pulp.....	.08	.60	.10	.8	.007	.008	86.7	
			Skin.....	.66	4.20	1.10	7.0	.013	.021	84.2	
23206 ²	Check (unsprayed).....	July 10	Whole ⁴	.12	.90	.0	.0	.010	.0	86.7	83.6
			Pulp.....	.07	.50	.0	.0	.005	.0	87.0	
			Skin.....	.29	2.00	.0	.0	.005	.0	85.3	
23207 ²	78 lbs. terra alba, 32 lbs. sulphur.	May 9 ³	Whole ⁴	.13	1.00	.0	.0	.012	.0	86.5	92.2
			Pulp.....	.02	.20	.0	.0	.001	.0	87.0	
			Skin.....	.63	4.00	.0	.0	.011	.0	84.3	
23208 ²	Do.....	May 26	Whole ⁴	.13	1.00	.0	.0	.012	.0	86.5	92.2
			Pulp.....	.02	.20	.0	.0	.001	.0	87.0	
			Skin.....	.63	4.00	.0	.0	.011	.0	84.3	
23209 ²	Do.....	July 10	Whole ⁴	.13	1.00	.0	.0	.012	.0	86.5	92.2
			Pulp.....	.02	.20	.0	.0	.001	.0	87.0	
			Skin.....	.63	4.00	.0	.0	.011	.0	84.3	
23210 ²	78 lbs. hydrated lime, 32 lbs. sulphur.	May 9 ³	Whole ⁴	.10	.80	.0	.0	.009	.0	86.7	88.4
			Pulp.....	.09	.70	.0	.0	.006	.0	87.1	
			Skin.....	.14	.90	.0	.0	.003	.0	85.0	
23211 ²	Do.....	May 26	Whole ⁴	.10	.80	.0	.0	.009	.0	86.7	88.4
			Pulp.....	.09	.70	.0	.0	.006	.0	87.1	
			Skin.....	.14	.90	.0	.0	.003	.0	85.0	
23212 ²	Do.....	July 10	Whole ⁴	.10	.80	.0	.0	.009	.0	86.7	88.4
			Pulp.....	.09	.70	.0	.0	.006	.0	87.1	
			Skin.....	.14	.90	.0	.0	.003	.0	85.0	
23213 ²	10 lbs. lead arsenate (powder), 90 lbs. hydrated lime.	May 9 ³	Whole ⁴	.13	.90	.30	2.1	.013	.030	85.4	101.8
			Pulp.....	.08	.60	.20	1.4	.007	.017	85.8	
			Skin.....	.35	2.10	.70	4.4	.006	.013	84.2	
23214 ²	Do.....	May 26	Whole ⁴	.13	.90	.30	2.1	.013	.030	85.4	101.8
			Pulp.....	.08	.60	.20	1.4	.007	.017	85.8	
			Skin.....	.35	2.10	.70	4.4	.006	.013	84.2	
23215 ²	Do.....	July 10	Whole ⁴	.13	.90	.30	2.1	.013	.030	85.4	101.8
			Pulp.....	.08	.60	.20	1.4	.007	.017	85.8	
			Skin.....	.35	2.10	.70	4.4	.006	.013	84.2	
23216 ²	8 lbs. sulphur, 3ozs. glue (used in water to wet sulphur), 8 lbs. hydrated lime, 1lb. lead arsenate (powder), 50 galls. water.	May 9 ³	Whole ⁴	.10	.70	.30	2.0	.009	.025	85.1	86.0
			Pulp.....	.04	.30	.10	.7	.003	.007	85.4	
			Skin.....	.34	2.10	1.00	6.3	.006	.018	84.1	
23217 ²	Do.....	May 26	Whole ⁴	.10	.70	.30	2.0	.009	.025	85.1	86.0
			Pulp.....	.04	.30	.10	.7	.003	.007	85.4	
			Skin.....	.34	2.10	1.00	6.3	.006	.018	84.1	
23218 ²	Do.....	July 10	Whole ⁴	.10	.70	.30	2.0	.009	.025	85.1	86.0
			Pulp.....	.04	.30	.10	.7	.003	.007	85.4	
			Skin.....	.34	2.10	1.00	6.3	.006	.018	84.1	

¹ Where no mention is made of water in the formula the material was applied as dust.

² Delaware variety, harvested Aug. 12-18, Berlin, Md.

³ As shucks fell.

⁴ Without stones.

TABLE 5.—Arsenic and lead remaining on sprayed peaches at picking time—Continued.

Sample No.	Spray material used.	Date sprayed.	Determinations made on.	Arsenic(As).		Lead (Pb).		Arsenic.	Lead.	Loss on drying.	Average weight of peach.
				Original fruit.	Dried fruit.	Original fruit.	Dried fruit.				
		1915.		Parts per million.				Mg. per peach.		P.ct.	Gr.
23205 ²	Sprayed lightly with 1 lb. lead arsenate (powder), 50 galls. water. 8 lbs. sulphur, 8 lbs. stonelime, 50 galls. water (self-boiled lime-sulphur), 1 lb. lead arsenate (powder). Self-boiled lime-sulphur.	May 9 ³	Whole ⁴	0.16	1.20	0.30	2.2	0.013	0.025	86.1	84.1
			Pulp.....	.04	.30	.10	.7	.003	.007	86.3	
			Skin.....	.60	4.10	1.00	6.8	.010	.018	85.3	
23206 ²	8 lbs. sulphur, 8 lbs. stonelime, 50 galls. water (self-boiled lime-sulphur), 1 lb. lead arsenate (powder). Self-boiled lime-sulphur.	May 26	Whole ⁴	.30	1.90	.70	4.4	.021	.049	84.0	69.5
			Pulp.....	.06	.40	.30	1.9	.003	.016	84.2	
			Skin.....	1.30	7.80	2.50	15.1	.018	.033	83.4	
23207 ²	8 lbs. sulphur, 8 lbs. stonelime, 50 galls. water (self-boiled lime-sulphur), 1 lb. lead arsenate (powder). Self-boiled lime-sulphur.	May 9 ³	Whole ⁴	.23	1.50	.60	4.0	.019	.050	85.0	83.4
			Pulp.....	.04	.30	.20	1.3	.002	.013	85.1	
			Skin.....	.96	6.30	2.10	13.7	.017	.037	84.7	
23208 ⁵	8 lbs. sulphur, 8 lbs. stone lime, 50 galls. water (self-boiled lime-sulphur), 1 lb. lead arsenate (powder). Self-boiled lime-sulphur.	May 26	Whole ⁴	.10	.60	.40	2.6	.008	.035	84.5	81.2
			Pulp.....	.03	.20	.20	1.3	.002	.013	84.6	
			Skin.....	.36	2.30	1.40	8.8	.006	.022	84.0	
23209 ⁵	48 lbs. hydrated lime, 2 lbs. lead arsenate (powder). 2 lbs. lead arsenate (powder), 32 lbs. hydrated lime, 16 lbs. sulphur. 16 lbs. sulphur, 34 lbs. hydrated lime.	May 9 ³	Whole ⁴	.21	1.40	.70	4.8	.014	.045	85.3	65.8
			Pulp.....	.08	.50	.40	2.7	.004	.020	85.4	
			Skin.....	.70	4.60	1.70	11.2	.010	.025	84.8	
23210 ⁵	32 lbs. sulphur, 4 lbs. lead arsenate (powder), 14 lbs. hydrated lime. 32 lbs. sulphur, 18 lbs. hydrated lime.	May 26	Whole ⁴	.67	4.40	1.40	9.1	.040	.083	84.6	59.3
			Pulp.....	.09	.60	.20	1.3	.004	.009	84.8	
			Skin.....	2.50	15.40	5.10	31.5	.036	.074	83.8	
23211 ⁵	44 lbs. sulphur, 6 lbs. lead arsenate (powder). Sulphur, with 5 per cent hydrated lime added.	May 9 ³	Whole ⁴	.30	2.00	1.20	7.9	.018	.070	84.8	58.7
			Pulp.....	.10	.70	.20	1.4	.004	.007	85.2	
			Skin.....	1.00	6.10	4.30	26.1	.014	.063	83.5	
23212 ⁵	50 galls. self-boiled lime-sulphur, 1 lb. lead arsenate (powder). Self-boiled lime-sulphur. Check (unsprayed).....	May 26	Whole ⁴	.02	.13	.0	.0	.001	.0	84.4	67.4
			Pulp.....	.00	.....	.0	.0	.000	.0	84.8	
			Skin.....	.05	.30	.0	.0	.001	.0	82.9	
23213 ⁵	78 lbs. terra alba, 32 lbs. sulphur. Do..... Do.....	May 26	Whole ⁴	.06	.40	.0	.0	.003	.0	85.1	55.8
			Pulp.....	.02	.14	.0	.0	.001	.0	85.6	
			Skin.....	.15	.90	.0	.0	.002	.0	83.4	

² Delaware variety, harvested Aug. 12-18, Berlin, Md.³ As shucks fell.⁴ Without stones.⁵ Delaware variety, harvested Aug. 12-18, Springfield, W. Va.

TABLE 5.—*Arsenic and lead remaining on sprayed peaches at picking time—Continued.*

Sample No.	Spray material used.	Date sprayed.	Determinations made on.	Arsenic(As).		Lead (Pb).		Arsenic.	Lead.	Loss on drying.	Average weight of peach.
				Original fruit.	Dried fruit.	Original fruit.	Dried fruit.				
		1915.		Parts per million.				Mg. per peach.		P.ct.	Gr.
23214 ⁵	78 lbs. hydrated lime, 32 lbs. sulphur.	May 9 ³	Whole ⁴	0.03	0.20	0.0	0.0	0.002	0.0	85.0	52.1
			Pulp.....	.03	.20	.0	.0	.001	.0	85.5	
			Skin.....	.06	.36	.0	.0	.001	.0	83.2	
23215 ⁵	Do..... 10 lbs. lead arsenate (powder), 90 lbs. hydrated lime.	May 26 July 10 May 9 ³	Whole ⁴	.12	.70	.40	2.4	.007	.024	83.4	56.3
			Pulp.....	.06	.40	.20	1.2	.003	.009	83.5	
			Skin.....	.40	2.40	1.40	8.2	.004	.015	83.0	
23216 ⁵	Do..... 8 lbs. sulphur, 3 ozs. glue (used in water to wet sulphur), 8 lbs. hydrated lime, 1 lb. lead arsenate (powder), 50 galls. water.	May 26 May 9 ³	Whole ⁴	.17	1.10	.40	2.6	.009	.024	84.9	54.6
			Pulp.....	.05	.30	.20	1.4	.002	.011	85.3	
			Skin.....	.58	3.50	1.20	7.3	.007	.013	83.5	
23440 ⁶	Do..... 8 lbs. sulphur, 3 ozs. glue (used in water to wet sulphur), 8 lbs. hydrated lime, 50 galls. water.	May 26 July 10									
23440 ⁶	Sprayed lightly with 2 lbs. lead arsenate (com. paste), 2 lbs. stone lime, 50 galls. water.	June 1	Whole ⁴	.18	1.80	.70	6.9	.017	.062	89.8	95.0
			Pulp.....	.04	.40	.20	2.1	.003	.012	90.4	
			Skin.....	.72	5.80	2.50	20.0	.014	.050	87.5	
23441 ⁶	2 lbs. lead arsenate (com. paste), 50 galls. self-boiled lime-sulphur (8-8-50). Self-boiled lime-sulphur (8-8-50).	June 19 July 29									
23441 ⁶	Same as No. 23440, but heavier applications.	Same as No. 23440	Whole ⁴	.36	3.70	.90	9.2	.032	.077	90.3	89.3
			Pulp.....	.07	.80	.20	2.1	.005	.014	90.8	
			Skin.....	1.37	11.80	3.20	27.6	.027	.063	88.4	
23442 ⁶	4 lbs. lead arsenate (com. paste), 4 lbs. stone lime, 50 galls. water.	June 1	Whole ⁴	.30	2.90	.80	7.8	.028	.076	89.7	95.1
			Pulp.....	.06	.60	.20	2.0	.004	.013	90.1	
			Skin.....	1.20	10.30	3.10	26.5	.024	.063	88.3	
23443 ⁶	4 lbs. lead arsenate (com. paste), self-boiled lime-sulphur (8-8-50). Self-boiled lime-sulphur (8-8-50).	June 19 July 29									
23443 ⁶	4 lbs. lead arsenate (powder), 96 lbs. hydrated lime.	May 30	Whole ⁴	.36	3.10	1.40	12.0	.040	.155	88.3	110.9
			Pulp.....	.08	.70	.20	1.7	.007	.017	88.5	
			Skin.....	1.50	11.90	6.30	50.0	.033	.138	87.4	
23444 ⁶	4 lbs. lead arsenate (powder), 32 lbs. sulphur (200-mesh fine), 64 lbs. hydrated lime.	June 19									
23444 ⁶	32 lbs. sulphur (200-mesh fine), 68 lbs. hydrated lime.	July 29									
13444 ⁶	8 lbs. lead arsenate (powder), 92 lbs. hydrated lime.	May 30	Whole ⁴	.67	5.60	2.00	16.8	.070	.209	88.1	104.5
			Pulp.....	.10	.90	.20	1.8	.008	.017	88.8	
			Skin.....	2.90	20.00	9.00	62.1	.062	.192	85.5	
13444 ⁶	8 lbs. lead arsenate (powder), 32 lbs. sulphur (200-mesh fine), 60 lbs. hydrated lime.	June 19									
13444 ⁶	64 lbs. sulphur (200-mesh fine), 36 lbs. hydrated lime.	July 29									

³ As shucks fell.⁴ Without stones.⁵ Delaware variety, harvested Aug. 12-18, Springfield, W. Va.⁶ Elberta variety, harvested Sept. 13, Benton Harbor, Mich.

TABLE 5.—Arsenic and lead remaining on sprayed peaches at picking time—Continued.

Sample No.	Spray material used.	Date sprayed.	Determinations made on.	Arsenic(As).		Lead (Pb).		Arsenic.	Lead.	Loss on drying.	Average weight of peach.	
				Original fruit.	Dried fruit.	Original fruit.	Dried fruit.					
				Parts per million.				Mg. per peach.		P.ct.	Gr.	
23445 ⁶	12 lbs. lead arsenate (powder), 88 lbs. hydrated lime.	1915. May 30	Whole ⁴	0.80	7.10	2.60	23.0	0.091	0.297	88.7	114.3	
			Pulp.....	.07	.60	.20	1.8	.006	.013	89.0		
			Skin.....	3.50	27.80	11.60	92.1	.085	.284	87.4		
23446 ⁶	12 lbs. lead arsenate (powder), 88 lbs. sulphur (200-mesh fine). 100 lbs. sulphur (200-mesh fine).	June 19									104.7	
		May 30	Whole ⁴	.42	4.00	1.10	10.4	.044	.115	89.4		
			Pulp.....	.10	1.00	.20	2.0	.008	.016	89.8		
23447 ⁴	2 lbs. lead arsenate (com. paste), 2 lbs. stone lime, 50 galls. water. 2 lbs. lead arsenate (com. paste), self-boiled lime-sulphur (8-8-50). Self-boiled lime-sulphur (8-8-50).	June 19	Skin.....	1.50	12.50	4.10	34.2	.036	.099	88.0	100.5	
		May 30	Whole ⁴	.20	1.80	.34	3.0	.020	.034	88.8		
			Pulp.....	.10	.90	.10	.9	.008	.010	89.1		
23448 ⁶	68 lbs. terra alba, 32 lbs. sulphur (200-mesh fine). Do..... Do.....	June 19	Skin.....	.60	4.90	1.20	9.8	.012	.024	87.8	107.5	
		May 30	Whole ⁴	.24	2.30	.60	5.7	.026	.065	89.4		
			Pulp.....	.07	.70	.20	1.9	.006	.020	89.8		
23449 ⁶	68 lbs. hydrated lime, 32 lbs. sulphur (200-mesh fine). Do..... Do.....	June 19	Skin.....	1.10	8.70	2.50	19.7	.020	.045	87.3	122.8	
		May 30	Whole ⁴	.94	8.00	2.40	20.5	.115	.295	88.3		
			Pulp.....	.14	1.20	.20	1.7	.014	.020	88.5		
23450 ⁶	10 lbs. lead arsenate (powder), 90 lbs. hydrated lime. Do..... Check plat (unsprayed).	June 19	Skin.....	4.50	35.40	12.20	96.1	.101	.275	87.3	114.2	
		May 30	Whole ⁴	.23	2.00	.40	3.4	.026	.046	88.3		
			Pulp.....	.10	.90	.14	1.2	.009	.013	88.5		
25637 ⁷	Check plat (unsprayed).	1916.	Skin.....	.77	6.10	1.50	11.9	.017	.033	87.4	129.4	
			Whole ⁴	.04	.30	.40	2.7	.005	.052	85.1		
			Pulp.....	.01	.10	.30	2.2	.001	.031	86.4		
25638 ⁷	Self-boiled lime-sulphur (8-8-50), 2 lbs. lead arsenate.	1916. May 1 ³	Skin.....	.20	1.20	.90	5.3	.004	.021	83.0	90.9	
			Whole ⁴	.05	.30	.50	3.4	.005	.045	85.4		
			Pulp.....	.01	.10	.40	2.9	.001	.028	86.2		
25639 ⁷	2 lbs. lead arsenate, 50 galls. water. 5 lbs. "soluble sulphur compd.," 3 lbs. lime, 50 galls. water, 2 lbs. lead arsenate. 4 lbs. "soluble sulphur compd.," 4 lbs. lime, 50 galls. water.	May 1 ³	Skin.....	.20	1.10	.90	5.2	.004	.017	82.6	102.3	
			Whole ⁴	.05	.30	.50	3.5	.005	.051	85.7		
			Pulp.....	.01	.10	.30	2.1	.001	.025	85.9		
25708 ⁸	Check plat (unsprayed).	3 weeks later	Skin.....	.20	1.20	1.30	7.7	.004	.026	83.1	85.5	
			Whole ⁴	.06	.40	.40	2.7	.005	.034	85.3		
			Pulp.....	.03	.20	.30	2.2	.002	.021	86.4		
25709 ⁸	1 lb. lead arsenate (powder), 2 lbs. stone lime, 50 galls. water. 1 lb. lead arsenate (powder), self-boiled lime-sulphur (8-8-50). Self-boiled lime-sulphur (8-8-50).	May 29	Skin.....	.20	1.20	.90	5.6	.003	.013	83.9	105.6	
		May 30	Whole ⁴	.08	.70	.40	3.7	.008	.042	89.1		
		June 20	Pulp.....	.03	.30	.30	2.9	.002	.025	89.5		
25709 ⁸	1 lb. lead arsenate (powder), 2 lbs. stone lime, 50 galls. water. 1 lb. lead arsenate (powder), self-boiled lime-sulphur (8-8-50). Self-boiled lime-sulphur (8-8-50).	June 21	Skin.....	.30	2.20	.90	6.6	.006	.017	86.3	105.6	
		Aug. 1										
		Aug. 2										

³ As shucks fell.⁴ Without stones.⁶ Elberta variety, harvested Sept. 13, Benton Harbor, Mich.⁷ Elberta variety, harvested Aug. 21, Springfield, W. Va.⁸ Elberta variety, harvested Sept. 16, Benton Harbor, Mich.

TABLE 5.—*Arsenic and lead remaining on sprayed peaches at picking time—Continued.*

Sample No.	Spray material used.	Date sprayed.	Determinations made on.	Arsenic(As).		Lead (Pb).		Arsenic.	Lead.	Loss on drying.	Average weight of peach.
				Original fruit.	Dried fruit.	Original fruit.	Dried fruit.				
27935 ⁹	1 lb. lead arsenate (powder), 2½ lbs. lime, 50 galls. water.	1917.		<i>Parts per million.</i>				<i>Mg. per peach.</i>		<i>P.ct.</i>	<i>Gr.</i>
		Apr. 4	Whole fruit.	0.05	0.30	1.00	6.9	0.004	0.095	85.5	95.0
			Pulp.....	.01	.10	.40	3.0	.001	.032	86.6	
	Apr. 19	Skin.....	.20	1.20	4.20	25.8	.003	.063	83.7		
	8 lbs. sulphur, 8 lbs. hydrated lime, 3 ozs. glue, 1 lb. lead arsenate (powder), 50 galls. water.										
		June 7	Whole fruit.	.0	.0	.60	4.0	.0	.057	85.0	95.4
27936 ⁹	Check (unsprayed).....		Pulp.....	.0	.0	.40	2.8	.0	.032	85.7	
			Skin.....	.0	.0	1.70	9.8	.0	.025	82.6	
		Apr. 4	Whole fruit.	.02	.10	.90	6.3	.002	.086	85.6	96.2
27937 ⁹	10 lbs. lead arsenate (powder), 90 lbs. hydrated lime.	Apr. 19	Pulp.....	.01	.10	.60	4.3	.001	.048	86.0	
			Skin.....	.04	.20	2.40	14.0	.001	.038	82.8	
		June 7	Whole fruit.	.07	.50	1.20	8.0	.006	.110	85.0	91.5
27938 ⁹	Commercial preparation containing 50 per cent sulphur and 50 per cent lead arsenate.	Apr. 4	Pulp.....	.0	.0	.80	5.6	.0	.062	85.6	
		Apr. 19									
		June 7	Skin.....	.40	2.30	3.30	19.2	.006	.048	82.6	

⁴ Without stones.⁹ Harvested July 9, Fort Valley, Ga.TABLE 6.—*Arsenic, lead, and copper remaining on sprayed cherries at picking time.*

Sample No.	Spray material used.	Date sprayed.	Condition of fruit analyzed.	Arsenic (As).		Lead (Pb).		Copper (Cu).		Loss on drying.
				Original fruit.	Dried fruit.	Original fruit.	Dried fruit.	Original fruit.	Dried fruit.	
		1916.		Parts per million.						P. ct.
25452 ¹	Check (unsprayed).....			0.02	0.16			0.5	4.0	87.5
25453 ¹	Home-made Bordeaux.....		Unwashed ¹	.04	.2			2.1	11.9	82.3
			Washed ²	.02	.1			1.4	7.9	
25454 ¹	Commercial fungicide containing 12 per cent copper, 3 per cent arsenic.		Unwashed ¹	.09	.7			2.0	15.0	86.7
			Washed ²	.07	.5			1.2	9.0	
25481 ³	3-4-50 Bordeaux, 2 lbs. lead arsenate (paste).	May 30, June 21.	Unwashed ¹	.15	.7	1.2	5.4	3.2	14.4	77.8
			Washed ²	.09	.4	.7	3.2	1.8	8.1	
25482 ³	Check (unsprayed).....	July 3.		.08	.4	.6	2.8	1.4	6.5	78.6
25483 ³	1½ galls. lime-sulphur solution, 2 lbs. lead arsenate (paste), 50 galls. water.	May 30, June 21.	Unwashed ¹	.15	.7	.6	2.8			78.9
			Washed ²	.10	.5	.4	1.9			
	1½ galls. lime-sulphur solution, 50 galls. water.	July 3.								
25484 ⁴	Check (unsprayed).....			.08	.6	.7	5.3	1.1	8.3	86.7
25485 ⁴	1½ galls. lime-sulphur, 2 lbs. lead arsenate (paste), 50 galls. water.	May 29-30, June 20.	Unwashed ¹	.16	1.0	1.3	8.1			83.9
			Washed ²	.16	1.0	1.3	8.1			
25486 ⁴	3-4-50 Bordeaux, 2 lbs. lead arsenate (paste).	May 29-30, June 20.	Unwashed ¹	.35	2.3	.7	4.6	2.3	15.2	84.9
			Washed ²	.17	1.1	.5	3.3	1.6	10.6	

¹ Picked July 12, 1916, Wenatchee, Wash.² Washed by holding under running tap water for a few minutes.³ Sweet cherries, picked July 20, 1916, Hart, Mich.⁴ Sour cherries, picked July 20, 1916, Hart, Mich.

TABLE 7.—*Arsenic, lead, and copper remaining on sprayed plums at picking time.*

Sam- ple No.	Spray material used.	Date sprayed.	Condition of fruit analyzed.	Arsenic (As).		Lead (Pb).		Copper (Cu).		Loss on dry- ing.
				Orig- inal fruit.	Dried fruit.	Orig- inal fruit.	Dried fruit.	Orig- inal fruit.	Dried fruit.	
1916.										
25640 ¹	2 lbs. lead arsenate (paste), 50 galls. water	May 26.	Unwashed.	0.06	0.5	0.2	1.6	0.3	2.4	P. ct.
	1 lb. com. spray con- taining 1.7 per cent copper, 5 per cent lead arsenate, 7 per cent calcium arsenate, 2 per cent sulphur, 50 galls. water.	June 22, Aug. 1, 2.	Washed ² ...	.06	.5	.2	1.6	.3	2.4	87.4
Parts per million.										
25641 ¹	2 lbs. lead arsenate (paste), 50 galls. water.	May 26.	Unwashed.	.04	.3	.4	3.1	-----	-----	87.0
	5 lbs. sulphur, 50 galls. water.	June 22, Aug. 1, 2.	Washed ² ...	.03	.2	.2	1.5	-----	-----	-----
25642 ¹	2 lbs. lead arsenate (paste), 50 galls. water.	May 26.	Unwashed.	.03	.2	.2	1.6	-----	-----	87.2
	4 lbs. barium polysul- phid, 50 galls. water.	June 22, Aug. 1, 2.	Washed ² ...	.03	.2	.2	1.6	-----	-----	-----
25643 ¹	2 lbs. lead arsenate (paste), 50 galls. water.	May 26.	Unwashed.	.04	.3	.2	1.6	-----	-----	87.7
	1 lb. sodium polysul- phid, 50 galls. water.	June 22, Aug. 1, 2.	Washed ² ...	.04	.3	.2	1.6	-----	-----	-----
25644 ¹	2 lbs. lead arsenate (paste), 50 galls. water.	May 26.	Unwashed.	.03	.2	.3	2.4	-----	-----	87.6
	Self-boiled lime-sul- phur (8-8-50).	June 22, Aug. 1, 2.	Washed ² ...	.02	.2	.2	1.6	-----	-----	-----
25645 ¹	2 lbs. lead arsenate (paste), 50 galls. water.	May 26.	Unwashed.	.03	.3	.2	1.7	-----	-----	88.1
	Self-boiled lime-sulphur (8-8-50), 2 lbs. soap...	June 22, Aug. 1, 2.	Washed ² ...	.03	.3	.2	1.7	-----	-----	-----
25646 ¹	Check (unsprayed).....	-----	Unwashed.	.03	.2	.3	2.2	0.5	3.7	86.6
			Washed ² ...	.02	.1	.2	1.4	.4	3.0	-----
25807 ³	2 lbs. lead arsenate (paste), plus lime, 50 galls. water.	May 27.	Unwashed.	.13	.8	.5	2.9	-----	-----	82.9
			Washed ² ...	.07	.4	.5	2.9	-----	-----	-----
	1½ galls. lime-sulphur solution, 50 galls. wa- ter, 2 lbs. lead arse- nate (paste).	June 21, 22, 23								
	1½ galls. lime-sulphur solution, 50 galls. water.	Aug. 12.								
25808 ³	2 lbs. lead arsenate (paste), 50 galls. water, plus lime.	May 27.	Unwashed.	.07	.4	.3	1.7	-----	-----	81.8
			Washed ² ...	.07	.4	.3	1.7	-----	-----	-----
	Self-boiled lime-sulphur (8-8-50), 2 lbs. lead arsenate (paste), 50 galls. water.	June 21, 22, 23								
	Self-boiled lime-sulphur (8-8-50).	Aug. 12.								
25809 ³	2 lbs. lead arsenate (paste), plus lime, 50 galls. water.	May 27.	Unwashed.	.13	.7	.4	2.3	1.2	6.8	82.3
			Washed ² ...	.10	.6	.4	2.3	.9	5.1	-----
	Bordeaux 3-4-50, 2 lbs. lead arsenate (paste).	June 21, 22, 23								
	Bordeaux 3-4-50.....	Aug. 12.								
25810 ³	Check (unsprayed).....	-----	Unwashed.	.10	.6	.4	2.3	.6	3.4	82.3
			Washed ² ...	.07	.4	.3	1.7	.6	3.4	-----

¹ Burbank; picked last of August, Hart, Mich.² Washed by holding under running tap water for a few minutes.³ Golden Domestic; picked last of September, Hart, Mich.

TABLE 8.—*Arsenic, lead, and copper remaining on sprayed tomatoes at picking time.*

Sample No.	Spray material used.	Date sprayed.	Determinations made on.	Arsenic (As).		Lead (Pb).		Copper (Cu).		Loss on drying.
				Original fruit.	Dried fruit.	Original fruit.	Dried fruit.	Original fruit.	Dried fruit.	
		1915.		<i>Parts per million.</i>						<i>P. ct.</i>
23304 ¹	Check (unsprayed).....		Whole fruit.	.....	.....	.....	.....	1.8	30.0	94.0
			Pulp.	.....	.....	.....	.....	1.2	20.0	94.0
23305 ¹	8-9-50 Bordeaux mixture.	July 8, 19, 21, 31, Aug. 5, 11, 18, Sept. 11.	Whole fruit.	.....	.....	.....	.....	5.7	91.9	93.8
			Pulp.	.....	.....	.....	.....	2.2	35.5	93.8
23306 ¹	5-6-50 Bordeaux.	July 8, 19, 20, 31, Aug. 5, 10, 18, Sept. 4, 11.	Whole fruit.	.....	.....	.....	.....	5.7	91.9	93.8
			Pulp.	.....	.....	.....	.....	1.6	25.8	93.8
		1916.		<i>Parts per million.</i>						
25664 ²	Check (unsprayed).....		Whole fruit.	0.02	0.4	0.9	16.1	.6	10.7	94.4
			Pulp.	.02	.4	.6	10.7	.5	8.9	94.4
25665 ²	5-5-50 Bordeaux, 1½ lbs. lead arsenate (powder).	July 13, Aug. 7, 25, Sept. 8.	Whole fruit.	.3	5.2	1.7	29.8	1.0	17.5	94.3
			Pulp.	.05	.9	1.2	21.1	.6	10.5	94.3
25825 ³	Check (unsprayed).....		Whole fruit.	.07	1.4	.3	6.0	.7	14.0	95.0
			Pulp.	.02	.4	.2	4.0	.7	14.0	95.0
25826 ³	5-5-50 Bordeaux, 1½ lbs. lead arsenate (powder).	July 13, Aug. 7, 25, Sept. 8.	Whole fruit.	.07	1.1	.5	7.6	4.0	60.6	93.4
			Pulp.	.02	.3	.2	3.3	.9	13.6	93.4
	5-5-50 Bordeaux.	Sept. 18.								
25706 ⁴	4-4-50 Bordeaux.		Whole fruit.	.....	.....	.....	.....	.9	17.0	94.7
			Pulp.	.....	.....	.....	.....	.5	9.4	94.7
25707 ⁴	Check (unsprayed).....		Whole fruit.	.....	.....	.....	.....	.6	10.5	94.3
			Pulp.	.....	.....	.....	.....	.5	8.8	94.3
25710 ⁴	Check (unsprayed).....		Whole fruit.	.....	.....	.....	.....	.7	13.2	94.7
			Pulp.	.....	.....	.....	.....	.7	13.2	94.7
25711 ⁴	4-4-50 Bordeaux.		Whole fruit.	.....	.....	.....	.....	.8	14.3	94.4
			Pulp.	.....	.....	.....	.....	.7	12.5	94.4

¹ Fruit picked Sept. 15, 1915, Camden, N. J.² Fruit picked Sept. 14, 1916, Arlington, Va.³ Fruit picked Oct. 2, 1916, Arlington, Va.⁴ Fruit picked Sept. 15, 1916, Salem, N. J.; samples represent commercial fruit ready for market.TABLE 9.—*Copper remaining on sprayed celery at gathering time.*¹

Sample No.	Spray material used.	Date sprayed.	Determinations made on.	Copper (Cu).		Loss on drying.
				Original celery.	Dried celery.	
		1915.		<i>Parts per million.</i>		<i>Per cent.</i>
23585 ²	Check plot (unsprayed).....		Unwashed (check)...	2.3	24.2	90.5
23586 ²	Oversprayed with 5-5-50 Bordeaux mixture, 2 lbs. resin fish-oil soap.	Aug. 14, 24, Sept. 2, 14.	Unwashed leaves ³ ...	258.1	2,150.8	88.0
			Unwashed stalks ³ ...	16.6	207.5	92.0
			Washed leaves ⁴	65.7	547.5	88.0
			Washed stalks ⁴	8.2	102.5	92.0
23587 ²	5-5-50 Bordeaux mixture, 2 lbs. resin fish-oil soap.	Aug. 14, 24, Sept. 2, 14.	Unwashed leaves ³ ...	213.0	1,775.0	88.0
			Unwashed stalks ³ ...	3.6	45.0	92.0
			Washed leaves ⁴	85.5	712.5	88.0
			Washed stalks ⁴	2.9	36.3	92.0
		1917.				
28783 ⁵	Commercially sprayed with 5-5-50 Bordeaux plus soap.	Sept. 11, 22, Oct. 1.	Unwashed leaves....	4.7	33.6	86.0
			Unwashed stalks....	.9	11.5	92.2
			Washed leaves ⁶	2.9	20.7	.....
			Washed stalks ⁶	.9	11.5	.....
28784 ⁵	Oversprayed with 5-5-50 Bordeaux plus soap.	Sept. 11, 22, Oct. 1.	Unwashed leaves....	12.8	90.4	86.0
			Unwashed stalks....	1.6	20.0	92.0
			Washed leaves ⁶	2.1	15.0	.....
			Washed stalks ⁶	.7	8.7	.....

¹ The samples sprayed in 1915 were coated with copper spray when received and represent extremely heavy applications; the 1917 samples represent celery as it usually appears on the market.² Harvested Oct. 29, 1915, North Liberty, Ind.³ These sprayed samples were heavily coated with the spray material when received.⁴ Washing done by holding sample under faucet water for few minutes.⁵ Harvested about Nov. 1, 1917, North Liberty, Ind.⁶ Washed by soaking celery in water for a short time and then rubbing with a small brush.

TABLE 10.—Copper remaining on sprayed cucumbers at picking time.

Sample No.	Spray material used.	Date sprayed.	Determinations made on.	Copper (Cu).		Loss on drying.
				Original fruit.	Dried fruit.	
				<i>Parts per million.</i>		<i>Per cent.</i>
25660 ¹	Check (unsprayed).....	1916	Whole fruit.....	0.6	11.3	94.7
			Pulp.....	.3	7.1	95.8
			Skin.....	.5	7.7	93.5
25661 ¹	2-4-50 Bordeaux.....	1916	Whole fruit.....	1.2	25.5	95.3
			Pulp.....	.3	7.3	95.9
			Skin.....	2.8	44.4	93.7
25662 ²	2-4-50 Bordeaux plus 2 lbs. resin fish-oil soap.	1916	Whole fruit.....	1.2	25.5	95.3
			Pulp.....	.3	7.3	95.9
			Skin.....	2.5	39.1	93.6
25663 ³	5-5-50 Bordeaux.....	1916	Whole fruit.....	1.4	28.6	95.1
			Pulp.....	.3	6.8	95.6
			Skin.....	2.5	38.5	93.5

¹ Cucumbers picked Sept. 9, 1916, Plymouth, Ind.

TABLE 11.—Arsenic, lead, and copper remaining on sprayed cranberries at picking time.

Sample No.	Spray material used.	Date sprayed.	Condition of fruit analyzed.	Arsenic (As).		Lead (Pb).		Copper (Cu).		Loss on drying.
				Original fruit.	Dried fruit.	Original fruit.	Dried fruit.	Original fruit.	Dried fruit.	
				Parts per million.						P. ct.
23453 ¹	Sprayed lightly with 4-4-50 Bordeaux, 2 lbs. resin fish-oil soap. ²	1915. June 24, July 26, Aug. 11, 28.	Unwashed . Washed ³...	.....	.....	.....	.....	7.4 7.1	62.7 60.2	88.2 88.2
23454 ¹	Sprayed medium with 4-4-50 Bordeaux, 2 lbs. resin fish-oil soap (normal spray for region). ²	do.....	Unwashed . Washed ³...	.....	.....	.....	.....	3.9 2.3	33.9 20.0	88.5 88.5
23455 ¹	Sprayed heavily with 4-4-50 Bordeaux, 2 lbs. resin fish-oil soap. ²	do.....	Unwashed . Washed ³...	.....	.....	.....	.....	7.6 4.8	66.1 41.7	88.5 88.5
23456 ¹	Oversprayed with 4-4-50 Bordeaux, 2 lbs. resin fish-oil soap. ²	June 10, July 10, 31, Aug. 16.	Unwashed . Washed ³...	.....	.....	.....	.....	33.3 16.2	268.5 130.6	87.6 87.6
23684 ⁴	Sprayed heavily with 4-4-50 Bordeaux, 2 lbs. resin fish-oil soap. ⁵	June 19, July 27, Aug. 12.	Unwashed . Washed ³...	.....	.....	.....	.....	2.0 1.7	15.0 12.8	86.7 86.7
23685 ⁴	Sprayed medium with 4-4-50 Bordeaux, 2 lbs. resin fish-oil soap (normal spray for region). ⁵	do.....	Unwashed . Washed ³...	.....	.....	.....	.....	2.0 1.8	14.4 12.9	86.1 86.1
23686 ⁴	Sprayed lightly with 4-4-50 Bordeaux, 2 lbs. resin fish-oil soap. ⁵	do.....	Unwashed . Washed ³...	.....	.....	.....	.....	2.6 2.4	17.9 16.5	85.5 85.5
23687 ⁴	Check (unsprayed) ⁵...	.....		.....	.....	.....	.....	.9	7.1	87.4
25727 ¹	Commercially sprayed with 3-3-50 Bordeaux, 2 lbs. resin fish-oil soap. ⁶	1916. June 26, July 27, Aug. 5, 25.	Unwashed . Washed ⁷...	.....	.....	.....	.....	7.2 3.0	62.1 25.9	88.4 88.4

¹ Early Black.² Harvested Sept. 18, 1915, Brown Mills, N. J.³ Washed by holding the berries in running tap water.⁴ Howe.⁵ Harvested Oct. 16, 1915, Brown Mills, N. J.⁶ Harvested Sept. 18, 1916, Brown Mills, N. J.⁷ Washed by soaking berries in water for a short time, pouring off the water, adding more water, and repeating operation three times.

TABLE 11.—*Arsenic, lead, and copper remaining on sprayed cranberries at picking time—Continued.*

Sample No.	Spray material used.	Date sprayed.	Condition of fruit analyzed.	Arsenic (As).		Lead (Pb).		Copper (Cu).		Loss on drying.
				Original fruit.	Dried fruit.	Original fruit.	Dried fruit.	Original fruit.	Dried fruit.	
		1916.		<i>Parts per million.</i>						<i>P. ct.</i>
26166	Sprayed lightly with 4-4-50 Bordeaux, 2 lbs. resin fish-oil soap, 2 lbs. lead arsenate (powder). ⁸	Aug. 1, 24.	Unwashed . Washed 7...	1.2 .8	8.7 5.8	4.8 2.5	34.8 18.1	5.5 2.3	39.8 16.7	86.2 86.2
26167	Sprayed normally with 4-4-50 Bordeaux, 2 lbs. resin fish-oil soap, 2 lbs. lead arsenate (powder). ⁸	do.....	Unwashed . Washed 7...	1.3 1.0	9.4 7.2	5.7 2.5	41.3 18.1	6.7 3.1	48.6 22.5	86.2 86.2
26168	Sprayed heavily with 4-4-50 Bordeaux, 2 lbs. resin fish-oil soap, 2 lbs. lead arsenate (powder). ⁸	do.....	Unwashed . Washed 7...	1.7 1.0	12.8 7.5	7.4 3.8	55.6 28.6	10.0 4.6	75.2 34.6	86.7 86.7
26169	Oversprayed with 4-4-50 Bordeaux, 2 lbs. arsenate (powder), 2 lbs. resin fish-oil soap. ⁸	Aug. 2, 24.	Unwashed . Washed 7...	2.5 1.0	19.1 7.6	9.2 4.4	70.2 33.6	11.4 3.7	87.0 28.2	89.9 86.6
26170	Check (unsprayed). ⁸		Unwashed . Washed 7...	.1 .1	.7 .7	.6 .6	4.4 4.4	1.0 1.0	7.4 7.4	86.5 86.5
27337 ¹	4-5-50 Bordeaux, 2 lbs. resin fish-oil soap. ⁹	June 24, Aug. 3.	Unwashed . Washed 7...	..... .....	..... .....	..... .....	..... .....	..... .....	..... .....	..... 87.2
27338 ¹⁰	10 lbs. lead arsenate (paste), 50 galls. water. ¹¹	July 22.	Unwashed . Washed 7...	.14 .14	1.1 1.1	1.5 .9	11.6 7.0	1.0	7.8	87.1
27339 ¹⁰	10 lbs. lead arsenate (paste), 2 lbs. laundry soap, 50 galls. water. ¹¹	July 22, 24.	Unwashed . Washed 7...	.16 .16	1.2 1.2	1.1 1.1	8.1 8.1	..... .....	..... .....	86.5
27340 ¹	5 lbs. lead arsenate (powder), 50 galls. water. ¹¹	June 28, Aug. 1.	Unwashed . Washed 7...	3.9 1.5	30.7 11.8	19.1 11.5	150.4 90.6	..... .....	..... .....	87.3
	3 lbs. lead arsenate (powder), 50 galls. water. ¹²	Aug. 19.	.....	.....	.....	.....	.....	.....	.....	.....
27346 ¹	4-5-50 Bordeaux, 2 lbs. resin fish-oil soap. ⁹	June 24, Aug. 3.	Unwashed . Washed 7...	..... .....	..... .....	..... .....	..... .....	3.0 1.6	23.4 12.5	87.2
27347 ¹⁰	10 lbs. lead arsenate (paste), 50 galls. water. ¹¹	July 22	Unwashed . Washed 7...	.14 .14	1.1 1.1	1.4 1.1	10.5 8.3	..... .....	..... .....	86.7
27348 ¹⁰	10 lbs. lead arsenate (paste), 2 lbs. laundry soap, 50 galls. water. ¹¹	July 22, 24.	Unwashed . Washed 7...	.15 .09	1.2 1.7	1.5 1.0	11.7 7.8	..... .....	..... .....	87.2
27349 ¹	5 lbs. lead arsenate (powder), 50 galls. water. ¹¹	June 28, Aug. 1.	Unwashed . Washed 7...	3.9 1.4	30.7 11.0	18.9 12.4	148.8 97.7	..... .....	..... .....	87.3
	3 lbs. lead arsenate (powder), 50 galls. water. ¹²	Aug. 19.	.....	.....	.....	.....	.....	.....	.....	.....
27181	Check (unsprayed). ¹¹	.....	Unwashed . Washed 7...	.02 .02	.14 .14	.4 .4	2.9 2.9	0.9 .7	6.4 5.0	86.0
		1917.								
28686	4 lbs. lead arsenate (powder), 50 galls. water, 2 lbs. caustic potash fish-oil soap. ¹³	June 26, July 26, 30.	Unwashed . Washed 7...	1.1 .6	9.6 5.3	4.5 2.9	39.5 25.4	..... .....	..... .....	88.6
28685	Check (unsprayed). ¹³	.....	Unwashed . Washed 7...	.01 .01	.08 .08	.7 .7	5.6 5.6	0.6 .6	4.8 4.8	87.6 87.6
28556	3 lbs. lime, 4 lbs. copper sulphate, 2 lbs. resin fish-oil soap, 50 galls. water. ¹³	June 28, Aug. 4, 20.	Unwashed . Washed 7...	.1 .1	.8 .8	.6 .6	4.9 4.9	1.3 1.2	10.6 9.8	87.8
28830	4 lbs. lead arsenate (powder), 2 lbs. caustic potash fish-oil soap, 50 galls. water. ¹³	June 26, July 26, 30.	Unwashed . Washed 7...	1.2 .3	10.0 2.5	4.8 1.9	40.0 15.8	..... .....	..... .....	88.0

¹ Early Black.⁷ Washed by soaking berries in water for a short time, pouring off the water, adding more water, and repeating operation three times.⁸ Harvested Oct. 9, 1916, Brown Mills, N. J.⁹ Harvested Sept. 23, 1916, East Wareham, Mass.¹⁰ Late Home.¹¹ Harvested Oct. 2, 1916, East Wareham, Mass.¹² Harvested Sept. 25, 1916, East Wareham, Mass.¹³ Harvested Oct., 1917, East Wareham, Mass.

Some of the samples from New Jersey reported in Table 11 represent plots which were purposely oversprayed and contain relatively large amounts of spray residues. The lots sprayed according to recommended schedule contain much less spray residue. Samples 27340 and 27349 show a comparatively large amount of spray residue, but these samples are from experimental plots which were sprayed late. The other Massachusetts samples show very little spray residue. The results indicate that when sprayed with the regulation spray and washed before using the berries contain but little spray material.

TABLE 12.—Copper, lead, and arsenic remaining on sprayed grapes at picking time.

Sample No.	Spray material used.	Date sprayed.	Condition of samples analyzed.	Arsenic (As).		Lead (Pb).		Copper (Cu).		Loss on drying.
				Original fruit.	Dried fruit.	Original fruit.	Dried fruit.	Original fruit.	Dried fruit.	
		1915.		<i>Parts per million.</i>						<i>P. ct.</i>
23565 ¹	2½ lbs. lead arsenate (powder), 4-4-50 Bordeaux. ²	June 4, July 16.	Unwashed. Washed ³ ..	0.25 .14	1.50 .80	2.6 2.4	15.1 14.0	0.8 .6	4.7 3.4	82.8
23566 ¹	1 lb. lead arsenate (powder), 4-4-50 Bordeaux. ²	do.....	Unwashed. Washed ³ ..	.13 .13	.80 .80	2.1 1.3	13.1 8.1	.7 .6	4.4 3.8	84.0
23567 ¹	Check plat (unsprayed) ²			.07	.40	1.1	6.8	.4	2.5	83.9
23571 ¹	Check plat (unsprayed) ²			.07	.40	1.6	3.2	.4	2.1	81.0
23572 ¹	3 lbs. lead arsenate (paste), 2 lbs. fish-oil soap, 3-3-50 Bordeaux (sprayed with coarse nozzle).	July 6.	Unwashed. Washed ³ ..	.44 .30	2.70 1.80	1.4 1.2	8.4 7.2	1.3 1.1	7.8 6.6	83.4
	3 lbs. lead arsenate (paste), 1 lb. laundry soap, 3-3-50 Bordeaux (sprayed with coarse nozzle). ⁴	July 19.								
23573 ¹	5 lbs. lead arsenate (paste), 2 lbs. fish-oil soap, 3-3-50 Bordeaux (sprayed with coarse nozzle).	July 6.	Unwashed. Washed ³ ..	.80 .35	4.80 2.10	2.4 1.3	14.4 7.8	1.5 1.1	9.0 6.6	83.3
	5 lbs. lead arsenate (paste), 1 lb. laundry soap, 3-3-50 Bordeaux (sprayed with coarse nozzle). ⁴	July 19.								
23574 ¹	5 lbs. lead arsenate (paste), 2 lbs. fish-oil soap, 3-3-50 Bordeaux (oversprayed, coarse nozzle).	July 6.	Unwashed. Washed ³ ..	.80 .35	4.70 2.10	8.2 2.4	48.5 14.2	1.8 1.4	10.7 8.3	83.1
	5 lbs. lead arsenate (paste), 1 lb. laundry soap, 3-3-50 Bordeaux (oversprayed, coarse nozzle). ⁴	July 19.								
23688 ¹	3 lbs. lead arsenate (paste), 3-3-50 Bordeaux (sprayed with trailers, using fine nozzles). ⁵	July 5, 17.	Unwashed. Washed ³ ..	.40 .40	1.90 1.90	1.5 1.2	7.1 5.7	1.2 .7	5.7 3.3	79.0
23689 ¹	3 lbs. lead arsenate (paste), 1 lb. laundry soap, 3-3-50 Bordeaux (sprayed with trailers, using fine nozzles) (normal schedule for this region). ⁵	do.....	Unwashed. Washed ³ ..	.82 .50	3.90 2.40	2.4 1.4	11.5 6.7	1.8 1.2	8.7 5.8	79.2

¹ Concord.² Harvested Oct. 9, 1915, Benton Harbor, Mich.³ Samples washed in running tap water.⁴ Harvested Oct. 9, 1915, North East, Pa.⁵ Harvested Oct. 27, 1915, North East, Pa.

TABLE 12.—Copper, lead, and arsenic remaining on sprayed grapes at picking time—Continued.

Sample No.	Spray material used.	Date sprayed.	Condition of samples analyzed.	Arsenic (As).		Lead (Pb).		Copper (Cu).		Loss on drying.
				Original fruit.	Dried fruit.	Original fruit.	Dried fruit.	Original fruit.	Dried fruit.	
				Parts per million.						P. ct.
23690 ¹	3 lbs. lead arsenate (paste), 1 lb. laundry soap, 3-3-50 Bordeaux (spray applied with fine nozzles set at rear of sprayer). ⁵	1915. July 5, 17.	Unwashed . Washed ³ ..	0.29 .22	1.40 1.00	0.9 .4	4.3 1.9	0.6 .3	2.9 1.4	79.0
25836 ¹	Check plat (unsprayed) ⁶	.....	Unwashed . Washed ³ ..	.0 .0	.0 .0	.5 .5	2.6 2.6	.9 .6	4.7 3.2	81.0
25837 ¹	1 gall. lime-sulphur, 33° B., 7 galls. water.	1916. Dormant spray.	Unwashed . Washed ³ ..	.05 .02	.26 .10	.7 .6	3.6 3.1	1.1 1.1	5.6 5.6	80.4
25838 ¹	4-4-50 Bordeaux ⁶	June 16.								
25838 ¹	8 lbs. Bordeaux (com. paste), 1 lb. lead arsenate (powder), 50 galls. water.	June 1, 12.	Unwashed . Washed ³ ..	.12 .07	.63 .37	.8 .6	4.2 3.2	1.4 1.1	7.4 5.8	81.1
	8 lbs. Bordeaux (com. paste), 50 galls. water.	Aug. 2.								
25903 ¹	Check plat (unsprayed) ⁷	.....	Unwashed . Washed ³ ..	.04 .04	.17 .17	.6 .6	2.6 2.6	.8 .4	3.4 1.7	76.5
25904 ¹	1 lb. soap, 1½ lbs. lead arsenate (powder), 3-3-50 Bordeaux (used trailers with medium nozzles). ⁷	July 6, 21.	Unwashed . Washed ³ ..	3.00 1.00	12.60 4.20	7.5 3.5	31.6 14.8	4.1 1.4	17.3 5.9	76.3
25905 ¹	1 lb. soap, 2½ lbs. lead arsenate (powder), 3-3-50 Bordeaux (used trailers with medium nozzles). ⁷	do.....	Unwashed . Washed ³ ..	.70 .60	3.20 2.70	3.9 2.8	17.7 12.7	2.1 1.3	9.5 5.5	78.0
25906 ¹	1 lb. soap, 2½ lbs. lead arsenate (powder), 3-3-50 Bordeaux (used trailers with medium nozzles).	do.....	Unwashed . Washed ³ ..	3.80 2.60	16.10 11.00	12.0 7.6	50.8 32.2	3.2 1.7	13.6 7.2	76.4
	1 lb. lime, 1 lb. soap, 2½ lbs. lead arsenate (powder), 50 galls. water (double application). ⁷	Aug. 12.								
25907 ¹	1 lb. soap, 1½ lbs. lead arsenate (powder), 3-3-50 Bordeaux (used trailers with fine nozzle). ⁷	July 6, 21.	Unwashed . Washed ³ ..	.30 .30	1.30 1.30	2.4 1.3	10.3 5.6	2.3 1.5	9.8 6.5	76.6
26016 ⁸	4-3-50 Bordeaux (medium set nozzle). ⁹	June 15.	Unwashed . Washed ³ ..	.15 .15	.60 .60	.7 .7	2.9 2.9	2.0 1.3	8.3 5.4	75.8
26017 ⁸	4-3-50 Bordeaux (medium set nozzle).	do.....	Unwashed . Washed ³ ..	1.80 .70	7.30 2.80	5.1 2.1	20.7 8.5	2.7 1.5	11.0 6.1	75.4
	2½ lbs. lead arsenate (powder), 2 lbs. laundry soap, 3-3-50 Bordeaux (sprayed with trailer, fine nozzle).	June 28.								
	2½ lbs. lead arsenate (powder), 1 lb. resin soap, 3-3-50 Bordeaux (sprayed with trailer, fine nozzle). ⁹	Aug. 4.								
26018 ⁸	4-3-50 Bordeaux (medium set nozzle).	June 15.	Unwashed . Washed ³ ..	3.70 .90	16.30 4.00	10.4 3.1	45.8 13.7	3.4 1.4	15.0 6.2	77.3
	2½ lbs. lead arsenate (powder), 2 lbs. laundry soap, 3-3-50 Bordeaux (sprayed with trailer, coarse nozzle).	June 28.								
	2½ lbs. lead arsenate (powder), 1 lb. resin soap, 3-3-50 Bordeaux (sprayed with trailer, coarse nozzle). ⁹	Aug. 4.								

¹ Concord.³ Samples washed in running tap water.⁵ Harvested Oct. 27, 1915, North East, Pa.⁶ Harvested Sept. 30, 1916, Benton Harbor, Mich.⁷ Harvested Oct. 6, 1916, North East, Pa.⁸ Catawba.⁹ Harvested Oct. 13, 1916, Sandusky, Ohio.

TABLE 12.—*Copper, lead, and arsenic remaining on sprayed grapes at picking time—Continued.*

Sam- ple No.	Spray material used.	Date sprayed.	Condition of samples analyzed.	Arsenic (As).		Lead (Pb).		Copper (Cu).		Loss on dry- ing.
				Orig- inal fruit.	Dried fruit.	Orig- inal fruit.	Dried fruit.	Orig- inal fruit.	Dried fruit.	
26019 *	4-3-50 Bordeaux (sprayed with me- dium set nozzle). 2½ lbs. lead arsenate (powder), 2 lbs. laun- dry soap, 3-3-50 Bor- deaux (oversprayed with trailer, coarse nozzle). 2½ lbs. lead arsenate (powder), 1 lb. resin soap, 3-3-50 Bor- deaux (oversprayed with trailer, coarse nozzle). ⁹	1916. June 15.	Unwashed .	4.00	16.30	12.6	51.3	4.4	18.0	<i>P. ct.</i> 75.4
			Washed ³ ...	1.00	4.10	4.9	19.9	2.0	8.1	
		June 28.								
26020 *	4-3-50 * Bordeaux (sprayed with me- dium set nozzle). 2½ lbs. lead arsenate (powder), 2 lbs. laun- dry soap, 3-3-50 Bor- deaux (sprayed with trailer, medium noz- zle). ⁹	June 15.	Unwashed .	2.80	12.70	6.2	28.2	3.1	14.1	78.0
			Washed ³ ...	1.00	4.50	3.2	14.6	1.7	7.7	
		June 28, July 12.								
26021 *	4-3-50 Bordeaux (sprayed with me- dium set nozzle). 2½ lbs. lead arsenate (powder), 2 lbs. laun- dry soap, 3-3-50 Bor- deaux (sprayed with trailer, medium noz- zle). 2½ lbs. lead arsenate (powder), 1 lb. resin soap, 2-3-50 Bor- deaux. ⁹	June 15.	Unwashed .	4.60	21.10	13.3	61.0	4.6	21.1	78.2
			Washed ³ ...	2.70	12.40	6.4	29.4	1.8	8.3	
		June 28, July 12.								
28881 *	3-3-50 Bordeaux (set nozzle). 1½ lbs. lead. arsenate (powder), 1 lb. resin fish-oil soap, 2-3-50 Bordeaux (trailer, medium nozzle) (schedule recommend- ed for this region). ¹¹	1917. June 18.	Unwashed .	3.20	16.00	8.1	40.5	2.7	13.5	80.0
			Washed ¹⁰ ..	1.30	6.50	3.7	18.5	2.0	10.0	
		July 2-4, 24- 25.								
28882 *	3-3-50 Bordeaux (set nozzle). 1½ lbs. lead arsenate (powder), 1 lb. resin fish-oil soap, 2-3-50 Bordeaux (trailer, medium nozzle). ¹¹	June 18-20.	Unwashed .	7.10	35.50	17.6	88.0	4.2	21.0	80.0
			Washed ¹⁰ ..	3.60	18.00	11.3	56.5	2.6	13.0	
		July 2-4, 24- 25, Aug. 14.								
28883 *	3-3-50 Bordeaux (set nozzle). 1½ lbs. lead arsenate (powder), 1 lb. resin fish-oil soap, 2-3-50 Bordeaux (sprayed with trailer, medium nozzle). 2½ lbs. lead arsenate (powder), 1 lb. resin fish-oil soap, 2-3-50 Bordeaux (sprayed with trailer, medium nozzle). ¹¹	June 18-20.	Unwashed .	6.20	30.10	15.5	75.2	3.7	18.0	79.4
			Washed ¹⁰ ..	3.30	16.00	8.6	41.7	2.8	13.6	
		July 2-4.								
		July 24-25.								

³ Samples washed in running tap water.⁸ Catawba.⁹ Harvested Oct. 13, 1916, Sandusky, Ohio.¹⁰ Samples washed by soaking the grapes in water for 5 minutes, pouring off the water, and then washing in running tap water.¹¹ Harvested Oct. 27, 1917, Sandusky, Ohio.

TABLE 12.—*Copper, lead, and arsenic remaining on sprayed grapes at picking time—Continued.*

Sample No.	Spray material used.	Date sprayed.	Condition of samples analyzed.	Arsenic (As).		Lead (Pb).		Copper (Cu).		Loss on drying.
				Original fruit.	Dried fruit.	Original fruit.	Dried fruit.	Original fruit.	Dried fruit.	
28884 ¹²	3-3-50 Bordeaux (sprayed with set nozzle).	1917. June 18-20.	Unwashed	<i>Parts per million.</i>						<i>P. ct.</i>
			Washed ¹⁰	5.70	31.10	13.0	71.0	4.3	23.5	81.7
28886 ⁸	2½ lbs. lead arsenate (powder), 1 lb. resin fish-oil soap, 2-3-50 Bordeaux (sprayed with trailer, medium nozzle). ¹³	July 2-4, 24-25.	Unwashed	4.40	24.00	12.0	65.6	3.3	18.0	.....
			Washed ¹⁰	1.30	6.70	3.9	20.0	1.7	8.7	.....
28887 ¹²	1½ lbs. lead arsenate (powder), 1 lb. resin fish-oil soap, 2-3-50 Bordeaux (sprayed with trailer, medium nozzle). ¹¹	June 18-20.	Unwashed	5.90	30.30	14.8	75.9	2.3	11.8	80.5
			Washed ¹⁰	1.30	6.70	3.9	20.0	1.7	8.7	.....
28888 ⁹	3-3-50 Bordeaux (sprayed with set nozzle). ¹¹	July 2-4, Aug. 14.	Unwashed	4.60	24.30	.....	.....	6.4	33.8	81.1
			Washed ¹⁰	1.80	9.50	.....	.....	4.2	22.2	.....
28889 ¹²	1 lb. calcium arsenate (powder), 1 lb. resin fish-oil soap, 2-3-50 Bordeaux (sprayed with trailer, medium nozzle). ¹³	June 18-20.	Unwashed	.08	.40	.9	4.5	1.5	7.6	80.2
			Washed ¹⁰	.08	.40	.9	4.5	1.3	6.6	.....
28890 ¹²	3-3-50 Bordeaux (sprayed with set nozzle). ¹¹	June 18-20.	Unwashed	.08	.40	.5	2.5	1.5	7.6	80.2
			Washed ¹⁰	.08	.40	.3	1.5	1.5	7.6	.....

⁸ Catawba.¹⁰ Samples washed by soaking the grapes in water for 5 minutes, pouring off the water, and then washing in running tap water.¹¹ Harvested Oct. 27, 1917, Sandusky, Ohio.¹² Ives.¹³ Harvested Oct. 18, 1917, Sandusky, Ohio.

WEATHER CONDITIONS.

Nos. 23565-67: Ideal for spraying during both applications; all foliage and fruit were covered.

Nos. 23571-74 and 23683-90: Heavy rain on July 8, which seemed to wash off a large amount of the spray material.

Nos. 25836-38 and 25903-07: No abnormal weather conditions reported.

Nos. 26016-21: Dry, hot, clear; season unusually dry.

Nos. 28881-89: Rainfall normal; in no case did rain interfere with the spraying, nor did rain fall before material was well dried.

The Michigan samples and the Pennsylvania samples mentioned in Table 12 that were sprayed according to normal schedule showed very little spray residue at harvest. Grapes sprayed in Sandusky, Ohio, according to the schedule formerly used in that region showed a decided spray residue on their surface at harvest. As this spray residue was no doubt due mainly to late spraying, the Bureau of Entomology has recommended a new schedule which is given under Sample 28881. Table 12 shows the composition of grapes sprayed according to the recommended schedule as compared with that of those sprayed under the schedule formerly used, as well as the composition of grapes sprayed under various experimental schedules.

TABLE 13.—Arsenic, lead, and copper remaining on sprayed pears at picking time.

Sample No.	Spray material used.	Date sprayed.	Determinations made on.	Arsenic (As).		Lead (Pb).		Copper (Cu).		Loss on drying.	Arsenic in pear (average).	Lead in pear (average).	Copper in pear (average).	Average weight, pear.
				Original fruit.	Dried fruit.	Original fruit.	Dried fruit.	Original fruit.	Dried fruit.					
				<i>Parts per million.</i>							<i>Mg.</i>	<i>Mg.</i>	<i>Mg.</i>	<i>Grams.</i>
23282 ¹	1 gall. lime-sulphur, 40 galls. water (normal schedule).	May 15.	Whole.....	0.32	2.1	1.0	6.7	1.5	10.0	85.0	0.049	0.151	0.227	151.6
23282 ¹	1 gall. lime-sulphur, 2½ lbs. lead arsenate (paste), 50 galls. water (normal schedule).	May 26.	Pulp.....	.08	.6	.2	1.4	.7	4.9	85.8	.010	.025	.095	
23282 ¹	4-4-50 Bordeaux, 2½ lbs. lead arsenate (paste) ² (normal schedule).	June 16.	Skin.....	1.00	4.3	3.2	13.7	4.5	19.3	76.7	.023	.073	.102	
			Calyx.....	6.40	27.7	21.3	92.2	12.1	52.4	76.9	.016	.053	.030	
			Skin ²	.47	2.0	2.4	10.3	2.1	9.0	76.7	.011	.054	.049	
			Calyx ²	6.40	27.7	21.3	92.2	7.8	33.8	76.9	.016	.053	.020	
23281 ¹	Check plat (unsprayed) ³ .		Whole.....	.06	.3	.20	1.0	.8	4.0	80.1	.008	.027	.110	132.8
23568 ⁴	1 lb. lead arsenate (powder), 1½ galls. lime-sulphur, 50 galls. water.	May 12.	do.....	.30	2.0	.9	6.1	.....	.....	85.2	.026	.077	.....	89.2
	1 lb. lead arsenate (powder), 1½ galls. lime-sulphur, 50 galls. water. ⁵	June 15-16.	Pulp.....	.10	.8	.2	1.7	.....	.....	88.0	.007	.015	.....	
			Skin.....	.90	4.0	3.0	13.4	.....	.....	77.6	.014	.045	.....	
			Calyx.....	5.10	23.4	17.2	78.9	.....	.....	78.2	.005	.017	.....	
			Skin ²	.90	4.0	3.0	13.4	.....	.....	77.6	.014	.045	.....	
			Calyx ²	5.10	23.4	17.2	78.9	.....	.....	78.2	.005	.017	.....	
23569 ⁴	½ lb. calcium arsenate (powder), 1½ galls. lime-sulphur, 50 galls. water.	May 13.	Whole.....	.22	1.3	.....	.....	.....	.....	83.5	.017	.....	.....	77.4
23569 ⁴	½ lb. calcium arsenate (powder), 1½ galls. lime-sulphur, 2 lbs. freshly-slaked stone lime, 50 galls. water. ⁵	June 16.	Pulp.....	.05	.4	.....	.....	.....	.....	88.4	.003	.....	.....	
			Skin.....	.60	2.9	.....	.....	.....	.....	79.3	.009	.....	.....	
			Calyx.....	6.00	27.1	.....	.....	.....	.....	77.9	.005	.....	.....	
			Skin ²	.60	2.9	.....	.....	.....	.....	79.3	.009	.....	.....	
			Calyx ²	6.00	27.1	.....	.....	.....	.....	77.9	.005	.....	.....	
23596	Check plat (unsprayed) ⁶ .		Whole.....	.08	.4	0.2	1.1	0.3	1.7	82.2	.009	0.022	0.033	111.2
25919 ⁶	Check plat (unsprayed) ⁷ .		do.....	.10	.6	.2	1.3	.....	.....	84.2	.013	.026	.....	128.0
25920 ⁸	Check plat (unsprayed) ⁷ .		do.....	.05	.3	.3	1.5	.9	4.5	80.1	.006	.037	.113	125.0

¹ Berlett.² Fruit wiped with dry cloth before peeling.³ Harvested Sept. 1, 1915, Benton Harbor, Mich.⁴ Kiefer.⁵ Harvested Oct. 9, 1915, Benton Harbor, Mich.⁶ Clarigeau.⁷ Harvested Sept. 30, 1916, Benton Harbor, Mich.⁸ Anjou.

TABLE 13.—*Arsenic, lead, and copper remaining on sprayed pears at picking time—Continued.*

Sam- ple No.	Spray material used.	Date sprayed.	Determina- tions made on.	Arsenic (As).		Lead (Pb).		Copper (Cu).		Loss on dry- ing.	Arsenic in pear (aver- age).	Lead in pear (aver- age).	Copper in pear (aver- age).	Aver- age weight, pear.
				Orig- inal fruit.	Dried fruit.	Orig- inal fruit.	Dried fruit.	Orig- inal fruit.	Dried fruit.					
25924*	1½ galls. lime-sulphur (32° B.), 50 galls. water. 14 galls. lime-sulphur, 24 lbs. lead arsenate (paste), 50 galls. water. ⁹	1916. May 14. May 24, June 13.	Whole.....	0.10	0.5	<i>Parts per million.</i>				<i>Per ct.</i>	Mg.	Mg.	Mg.	Grams
			Pulp.....	.05	.3	0.3	1.6			81.3	0.013	0.039	130.0	
			Skin.....	.30	1.2	.3	1.3			84.4	.006	.022		
			Calyx.....	1.20	4.8	4.2	16.7			74.4	.005	.012		
			Skin ¹⁰	.80	1.2	.8	3.1			74.8	.002	.005		
25925*	1 gall. lime-sulphur, 9 galls. water..... 14 galls. lime-sulphur, 50 galls. water..... 1 gall. lime-sulphur, 2 lbs. lead arsenate (paste), 50 galls. water. 3 qts. lime-sulphur, 2 lbs. lead arsenate (paste), 50 galls. water. 3-3-50 Bordeaux ⁹ .	Apr. 19. May 3. May 24. June 13. Aug. 16.	Calyx ¹⁰	1.20	4.8	4.2	16.7			74.8	.002	.005		
			Whole.....	.10	.5	.4	1.9	3.0	14.5	79.3	.014	.055	0.411	
			Pulp.....	.04	.2	1.5	5.0	1.0	5.1	80.3	.005	.024	.120	
			Skin.....	.40	1.3	1.5	5.0	16.2	54.5	70.3	.006	.024	.261	
			Calyx.....	1.80	5.7	5.5	17.3	21.9	68.9	68.2	.003	.007	.030	
25926*	14 galls. lime-sulphur (32° B.), 4 lbs. stone lime, 1 lb. lead arsenate (powder), 50 galls. water. ⁹	May 16, 26, June 22.	Skin ¹⁰	.40	1.3	1.5	5.0	12.4	41.8	70.3	.006	.024	.200	
			Calyx ¹⁰	1.80	5.7	5.5	17.3	8.2	25.8	68.2	.003	.007	.011	
			Whole.....	.10	.5	.4	1.9			78.8	.016	.066	164.0	
			Pulp.....	.02	.1	.2	1.0			80.2	.003	.029		
			Skin.....	.40	1.2	1.2	3.5			66.0	.007	.021		
<i>10 Fruit wiped with damp cloth.</i>														
			Calyx.....	4.40	12.6	11.9	34.2			65.2	.006	.016		
			Skin ¹⁰	.40	1.2	1.2	3.5			66.0	.007	.021		
			Calyx ¹⁰	4.40	12.6	11.9	34.2			65.2	.006	.016		
			Whole.....	.10	.5	.4	1.9			78.8	.016	.066		
			Pulp.....	.02	.1	.2	1.0			80.2	.003	.029		

⁹ Harvested Oct. 7, 1916, Benton Harbor, Mich.

* Clarigeau. * Anjou.

TABLE 14.—Arsenic, lead, and copper remaining on sprayed apples at picking time.

Sam- ple No.	Spray material used.	Date sprayed.	Determina- tions made on.	Arsenic (As).		Lead (Pb).		Copper (Cu).		Loss on dry- ing.	Arsenic in apple (aver- age).	Lead in apple (aver- age).	Copper in apple (aver- age).	Aver- age weight, apple.
				Orig- inal fruit.	Dried fruit.	Orig- inal fruit.	Dried fruit.	Orig- inal fruit.	Dried fruit.					
		1915.												
23708 ¹	Check plat (unsprayed) ² , 1½ galls. lime-sulphur solution, 1 lb. lead arsenate (powder), 50 galls. water. ²	Apr. 26, May 16, 27, June 16.	Whole.....	0.09	0.7	0.2	1.5	0.3	2.3	86.9	0.007	0.019	Mg. 0.024	Grams. 80.7
23709 ¹			do.....	.10	.7	.3	2.2	.....	.....	86.2	.012	.036	.....	121.7
			Pulp.....	.06	.5	.2	1.6	.....	.....	87.8	.006	.020	.....	
			Skin.....	.30	1.7	.8	4.6	.....	.....	82.6	.004	.010	.....	
	10 lbs. com. dry Bordeaux, 1 lb. lead arsen- ate (powder), 50 galls. water. ²	do.....	Calyx.....	1.30	8.3	3.5	22.4	.....	.....	84.4	.001	.003	.....	
			Stem ends.....	.90	6.5	2.9	21.0	.....	.....	86.2	.001	.003	.....	
			Skin ²	.30	1.7	.8	4.6	.....	.....	82.6	.004	.010	.....	
			Calyx ²	1.30	8.3	3.5	22.4	.....	.....	84.4	.001	.003	.....	
			Stem ends ²	.90	6.5	2.9	21.0	.....	.....	86.2	.001	.003	.....	
			Whole.....	.18	1.2	.6	3.9	1.4	9.1	84.6	.016	.054	127	90.6
			Pulp.....	.06	.4	.2	1.3	.6	4.0	85.0	.005	.015	.046	
			Skin.....	.50	2.4	1.7	8.1	3.2	15.2	79.0	.008	.020	.039	
	Check plat (unsprayed) ⁵ , 10 lbs. lead arsenate (paste), 200 galls. water (coarse nozzle, 185 lbs. pressure).	April 30.	Calyx.....	3.90	19.7	13.6	68.7	29.5	149.0	80.2	.004	.014	.032	
			Stem ends.....	1.10	7.1	3.6	23.4	7.6	49.3	84.6	.001	.005	.010	
			Skin ²	.50	2.4	1.7	8.1	3.2	15.2	79.0	.005	.020	.039	
			Calyx ²	3.90	19.7	13.6	68.7	14.7	74.2	80.2	.004	.014	.016	
23283 ⁴	5 lbs. lead arsenate (powder), 200 galls. water (fine nozzle, 200 lbs. pressure). ⁵	May 13, June 19.	Stem ends ²	1.10	7.1	3.6	23.4	7.6	49.3	84.6	.001	.005	.010	
23284 ⁴			Whole.....	.16	1.0	.5	3.2	.....	.....	84.4	.021	.064	.....	128.8
			Pulp.....	.80	5.1	2.6	16.5	.....	.....	84.2	.074	.242	.....	93.0
			Skin.....	.10	.7	.2	1.4	.....	.....	85.5	.007	.015	.....	
	75 lbs. lime, 25 lbs. lead arsenate (41 lbs. in plat) (dust applications). (38.5 lbs. applied to 40 trees) (22.5 lbs. applied to 40 trees) (26 lbs. applied to 40 trees) (32 lbs. applied to 40 trees) ⁶	Apr. 27.	Calyx.....	3.00	15.5	11.0	57.0	.....	.....	82.7	.014	.039	.....	149.0
			Stem ends.....	8.00	46.2	25.6	148.0	.....	.....	82.7	.014	.046	.....	
			Skin ²	3.00	15.5	11.0	57.0	.....	.....	83.2	.014	.038	.....	
			Calyx ²	8.00	46.2	25.6	148.0	.....	.....	82.7	.014	.046	.....	
		Stem ends ²	6.50	38.7	17.1	101.8	.....	.....	83.2	.014	.038	.....		
		Whole.....	.46	2.8	1.3	7.9	.....	.....	83.5	.069	.194	.....		
		Pulp.....	.08	.5	.2	1.3	.....	.....	84.0	.010	.024	.....		
		Skin.....	1.40	7.3	4.0	20.9	.....	.....	80.9	.027	.076	.....		
	75 lbs. lime, 25 lbs. lead arsenate (41 lbs. in plat) (dust applications). (38.5 lbs. applied to 40 trees) (22.5 lbs. applied to 40 trees) (26 lbs. applied to 40 trees) (32 lbs. applied to 40 trees) ⁶	May 10. June 19. July 21. Aug. 9.	Calyx.....	4.40	23.0	12.6	71.6	.....	.....	82.4	.015	.044	.....	
			Stem ends.....	5.20	30.8	15.7	92.9	.....	.....	83.1	.017	.050	.....	
			Skin ²	1.40	7.3	4.0	20.9	.....	.....	80.9	.027	.076	.....	
			Calyx ²	4.40	23.0	12.6	71.6	.....	.....	82.4	.015	.044	.....	

For footnote references see page 47.

TABLE 14.—Arsenic, lead, and copper remaining on sprayed apples at picking time—Continued.

Sample No.	Spray material used.	Date sprayed.	Determinations made on.	Arsenic (As).		Lead (Pb).		Copper (Cu).		Loss on drying.	Arsenic in apple (average).	Lead in apple (average).	Copper in apple (average).	Average weight, apple.
				Original fruit.	Dried fruit.	Original fruit.	Dried fruit.	Original fruit.	Dried fruit.					
23303 *	45 lbs. lime, 40 lbs. sulphur, 15 lbs. lead arsenate (57 lbs. applied to trees of medium size; 40 trees in plot) (dust applications) (35 lbs. applied to 40 trees) (33.5 lbs. applied to 40 trees) (39 lbs. applied to 40 trees) (39 lbs. lead arsenate (paste), 200 galls. water (coarse nozzle, 140 lbs. pressure) 5 lbs. lead arsenate (powder), 200 galls. water (fine nozzle, 140 lbs. pressure). ⁷	1915. Apr. 27.	Whole.....	0.40	2.6	Parts per million.				84.7	0.061	0.183	Mg.	152.9
			Pulp.....	.08	.5	1.2	7.8			85.3	.010	.025		
			Skin.....	1.30	6.9	4.0	21.3			85.3	.026	.079		
			Calyx.....	3.30	18.5	10.9	61.2			82.2	.014	.043		
			Stem ends.....	4.10	25.0	12.9	78.7			83.6	.011	.038		
			Skin ²	1.30	6.9	4.0	21.3			81.2	.026	.079		
			Calyx ²	3.30	18.5	10.9	61.2			82.2	.011	.038		
			Stem ends ²	4.10	25.0	12.9	78.7			83.6	.014	.043		
			Whole.....	.80	5.2	2.2	14.3			84.6	.099	.271		
			Pulp.....	.20	1.3	2.4	2.7			85.1	.021	.041		
23435 *	10 lbs. lead arsenate (paste), 200 galls. water (coarse nozzle, 140 lbs. pressure) 5 lbs. lead arsenate (powder), 200 galls. water (fine nozzle, 140 lbs. pressure). ⁷	May 13, June 19, July 26.	Skin.....	2.70	14.9	8.0	44.2			81.9	.043	.126		123.4
			Calyx.....	8.30	48.5	25.3	147.9			82.9	.016	.048		
			Stem ends.....	9.50	59.4	27.9	174.4			84.0	.019	.056		
			Skin ²	2.70	14.9	8.0	44.2			81.9	.043	.126		
			Calyx ²	8.30	48.5	25.3	147.9			82.9	.016	.048		
			Stem ends ²	9.50	59.4	27.9	174.4			84.0	.019	.056		
			Whole.....	1.10	7.1	3.3	21.4			84.6	.102	.306		92.8
			Pulp.....	.20	1.4	1.2	5.4			85.6	.016	.032		
			Skin.....	3.70	18.3	11.2	55.4			79.8	.042	.126		
			Calyx.....	18.00	94.7	58.3	306.8			83.0	.018	.058		
23597 ¹⁰	10 lbs. lead arsenate (paste), 200 galls. water (coarse nozzle, 165 lbs. pressure). ¹	Apr. 30.	Skin ²	3.70	18.3	11.2	55.4			82.2	.026	.090		103.6
			Stem ends.....	21.70	121.9	75.2	422.5			79.8	.042	.126		
			Skin ²	3.70	18.3	11.2	55.4			83.0	.018	.058		
			Calyx ²	18.00	94.7	58.3	306.8			83.0	.018	.058		
			Stem ends ²	1.60	10.5	4.8	31.4			82.7	.022	.073		
			Whole.....	1.60	10.5	4.8	31.4			84.7	.106	.401		
			Pulp.....	.20	1.4	1.2	5.4			85.2	.017	.044		
			Skin.....	5.00	26.0	14.8	77.1			80.8	.008	.200		
			Calyx.....	21.10	109.9	68.0	394.2			80.8	.027	.088		
			Stem ends.....	36.20	205.7	110.2	626.1			82.4	.054	.165		
23598 ¹⁰	5 lbs. lead arsenate (powder), 200 galls. water (coarse nozzle, 165 lbs. pressure). ¹¹	May 14, June 20, July 24.	Skin ²	3.90	20.3	11.3	58.9			80.8	.053	.132		108.5
			Calyx ²	15.00	78.1	37.5	195.3			80.8	.019	.049		
			Stem ends ²	28.50	161.9	79.7	452.8			82.4	.043	.120		
			Whole.....	2.90	18.6	8.4	53.8			84.4	.314	.911		
			Pulp.....	.20	1.3	3.0	4.7			85.0	.018	.064		
			Skin.....	10.40	53.3	30.1	154.4			80.5	.141	.409		
			Calyx.....	27.20	140.2	81.5	420.1			80.6	.038	.114		
			Stem ends.....	78.10	464.9	216.3	1,287.5			83.2	.117	.324		
			Skin ²	3.40	17.4	11.7	60.0			80.5	.046	.139		
			Calyx ²	15.90	82.0	38.4	197.9			80.6	.022	.064		
23599 ¹⁰	5 lbs. lead arsenate (powder), 200 galls. water (fine nozzle, 200 lbs. pressure) purposely oversprayed. ¹¹	May 14, June 20, July 24.	Stem ends ²	56.40	335.7	130.4	776.2			83.2	.085	.196		
			Whole.....	10.40	53.3	30.1	154.4			80.5	.141	.409		
			Pulp.....	.20	1.3	3.0	4.7			85.0	.018	.064		
			Skin.....	10.40	53.3	30.1	154.4			80.5	.141	.409		
			Calyx.....	27.20	140.2	81.5	420.1			80.6	.038	.114		
			Stem ends.....	78.10	464.9	216.3	1,287.5			83.2	.117	.324		
			Skin ²	3.40	17.4	11.7	60.0			80.5	.046	.139		
			Calyx ²	15.90	82.0	38.4	197.9			80.6	.022	.064		
			Stem ends ²	56.40	335.7	130.4	776.2			83.2	.085	.196		
			Whole.....	10.40	53.3	30.1	154.4			80.5	.141	.409		

23923s 23924	Check plat (unsprayed) 11. 1½ galls. lime-sulphur (32° B.), 50 galls. water	Apr. 27.	Whole. do.	30	1.9	1.0	6.4	84.4	.025	.084	83.9 128.8
			Pulp.....	.37	2.4	3.4	2.7	84.5	.045	.....	
			Skin.....	.10	4.8	4.4	2.7	85.4	.011	.....	
			Calyx.....	1.00	4.8	3.4	16.3	79.2	.017	.057	
	1 lb. lead arsenate (powder), 1½ galls. lime-sulphur (32° B.), 50 galls. water (sprayed to a drip). ¹²	May 15, June 11, Aug. 10.	Stem ends.....	3.40	18.4	10.2	55.1	81.5	.006	.018	
			Skin ³	7.30	49.3	20.1	135.8	85.2	.014	.040	
			Calyx ³	3.40	4.8	3.4	16.3	79.2	.017	.057	
			Stem ends ³	3.40	18.4	10.2	55.1	81.5	.006	.018	
			Whole.....	7.30	49.3	20.1	135.8	85.2	.014	.040	118.9
	1½ galls. lime-sulphur (32° B.), 50 galls. water	Apr. 27.	Pulp.....	.17	1.1	.....	.....	84.3	.020	.....	
			Skin.....	.30	1.5	.....	.....	85.8	.010	.....	
			Calyx.....	.30	1.5	.....	.....	80.3	.005	.....	
	2 lbs. calcium arsenate (paste) (12.5 per cent As ₂ O ₃), 1½ galls. lime-sulphur, 50 galls. water (sprayed to a drip) (fine nozzle, 180-225 lbs. pressure). ¹²	May 14.	Stem ends.....	1.80	10.7	.....	.....	83.2	.004	.....	
			Skin ³	.40	2.7	.....	.....	85.3	.001	.....	
			Calyx ³	.30	1.5	.....	.....	80.3	.005	.....	
			Stem ends ³	1.80	10.7	.....	.....	83.2	.004	.....	
	1½ galls. lime-sulphur (32° B.), 50 galls. water.	Apr. 27.	Whole.....	.26	1.6	.....	.....	85.3	.001	.....	
			Pulp.....	.10	1.7	0.8	5.0	84.1	.028	.088	110.4
			Skin.....	.80	3.7	2.8	2.0	85.2	.009	.031	
			Calyx.....	2.40	13.0	4.6	24.9	78.5	.011	.041	
	1 lb. lead arsenate (powder), 1½ galls. lime-sulphur, 50 galls. water (fine nozzle, 180-225 lbs. pressure). ¹²	May 17.	Stem ends.....	1.90	12.3	4.5	29.0	81.5	.004	.008	
			Skin ³	.80	3.7	2.8	13.0	84.5	.004	.008	
			Calyx ³	2.40	13.0	4.6	24.9	78.5	.011	.041	
			Stem ends ³	1.90	12.3	4.5	29.0	81.5	.004	.008	
	1½ galls. lime-sulphur (32° B.), 50 galls. water.	Apr. 28.	Whole.....	.34	2.0	.....	.....	84.5	.004	.008	116.7
			Pulp.....	.10	5.6	.....	.....	82.8	.039	.....	
			Skin.....	1.20	5.6	.....	.....	84.6	.010	.048	
	5½ ozs. Paris green, 4+50 Bordeaux, 1 lb. strong lime (sprayed to a drip) (fine nozzle, 180-225 lbs. pressure). ¹²	May 17.	Calyx.....	2.20	10.3	.....	.....	78.6	.020	.010	
			Stem ends.....	2.80	16.3	.....	.....	81.3	.004	.011	
			Skin ³	1.20	5.6	.....	.....	82.8	.005	.012	
			Calyx ³	2.20	10.3	.....	.....	78.6	.020	.010	
			Stem ends ³	2.80	16.3	.....	.....	81.3	.004	.011	
	1½ galls. lime-sulphur (32° B.), 50 galls. water.	Apr. 28.	Whole.....	.40	2.4	1.3	7.7	82.8	.005	.012	129.9
			Pulp.....	.10	5.9	.....	.....	83.1	.032	.168	
			Skin.....	1.20	5.9	.....	.....	85.3	.011	.039	
	1 lb. lead arsenate (powder), 1½ galls. lime-sulphur, 50 galls. water (fine nozzle, 110 lbs. pressure) (sprayed to a very mild drip). ¹²	May 17, June 11, Aug. 10.	Calyx.....	3.00	16.5	8.8	2.0	79.5	.020	.062	
			Stem ends.....	5.60	36.8	18.1	48.7	81.8	.007	.019	
			Skin ³	3.20	3.9	3.7	125.7	84.8	.014	.048	
			Calyx ³	3.20	16.5	8.8	18.0	79.5	.020	.062	
			Stem ends ³	5.60	36.8	19.1	125.7	81.8	.007	.019	
			Whole.....	5.00	36.8	19.1	125.7	84.8	.014	.048	
	1½ galls. lime-sulphur (32° B.), 50 galls. water.	Apr. 28.	Pulp.....	.70	4.5	2.1	13.5	84.5	.083	.249	118.6
			Skin.....	.66	13.2	7.3	2.0	85.3	.005	.035	
			Calyx.....	2.80	38.0	34.4	34.4	78.5	.043	.112	
	1 lb. lead arsenate (powder), 1½ galls. lime-sulphur, 50 galls. water (sprayed to a strong drip) (larger nozzle, 210 lbs. pressure). ¹²	May 17, June 11, Aug. 10.	Stem ends.....	6.80	38.0	19.0	106.1	82.1	.013	.036	
			Skin ³	10.70	69.9	33.0	215.7	84.7	.021	.066	
			Calyx ³	1.40	6.6	4.2	19.8	78.8	.021	.066	
			Stem ends ³	6.80	38.0	19.0	106.1	82.1	.013	.036	
			Whole.....	6.60	43.1	16.4	107.2	84.7	.013	.032	

For footnote references see page 47.

TABLE 14.—Arsenic, lead, and copper remaining on sprayed apples at picking time.—Continued.

Sample No.	Spray material used.	Date sprayed.	Determinations made on.	Arsenic (As).		Lead (Pb).		Copper (Cu).		Loss on drying.	Arsenic in apple (average).	Lead in apple (average).	Copper in apple (average).	Average weight, apple.
				Original fruit.	Dried fruit.	Original fruit.	Dried fruit.	Original fruit.	Dried fruit.					
23831	1½ galls. lime-sulphur (32° B.), 50 galls. water. 2½ lbs. lead arsenate (powder), 1½ galls. lime-sulphur (32° B.), 50 galls. water (sprayed to a drip) (fine nozzle, 180 lbs. pressure). ¹²	1915. Apr. 28, 1915. May 17, June 12, Aug. 10.	Whole.....	0.90	6.0	2.9	19.2	.....	.....	Per ct.	Mg.	Mg.	Mg.	Grams.
			Pulp.....	.06	.4	.3	2.0	.....	.....	84.9	0.119	0.384	.....	132.4
			Skin.....	3.50	17.2	10.2	50.0	.....	.....	85.5	.007	.039	.....	.....
			Calyx.....	9.60	52.7	34.0	186.8	.....	.....	79.6	.064	.188	.....	.....
			Stem ends.....	15.30	100.0	43.0	313.7	.....	.....	81.8	.031	.096	.....	.....
23832	1½ galls. lime-sulphur (32° B.), 50 galls. water. 10 lbs. lead arsenate (powder), 50 lbs. hydrated lime, 40 lbs. sulphur (dust applications). ¹²	Apr. 28. May 14, June 10, Aug. 9.	Skin.....	2.20	10.8	9.5	46.6	.....	.....	84.7	.040	.174	.....	.....
			Calyx.....	8.50	46.7	18.5	101.6	.....	.....	81.8	.015	.033	.....	.....
			Stem ends.....	9.90	37.0	37.0	241.8	.....	.....	84.7	.020	.074	.....	.....
			Whole.....	.50	3.0	1.5	9.1	.....	.....	83.6	.083	.191	.....	127.1
			Pulp.....	.14	.9	.4	2.5	.....	.....	84.1	.015	.041	.....	.....
23833	1½ galls. lime-sulphur (32° B.), 50 galls. water. 25 lbs. lead arsenate (powder), 75 lbs. sulphur (dust applications). ¹²	Apr. 28. May 14, June 10, Aug. 9.	Skin.....	1.20	5.4	3.6	16.1	.....	.....	77.6	.019	.058	.....	.....
			Calyx.....	5.60	27.9	17.5	87.1	.....	.....	79.9	.011	.035	.....	.....
			Stem ends.....	8.30	49.1	26.0	153.8	.....	.....	83.1	.018	.057	.....	.....
			Skin.....	1.20	5.4	3.6	16.1	.....	.....	77.6	.019	.058	.....	.....
			Calyx.....	2.90	14.4	11.4	56.7	.....	.....	79.9	.006	.023	.....	.....
23834	1½ galls. lime-sulphur (32° B.), 50 galls. water. 15 lbs. lead arsenate (powder), 40 lbs. sulphur, 45 lbs. terra alba (dust applications). ¹²	Apr. 28. May 14, June 10, Aug. 9.	Stem ends.....	8.30	49.1	26.0	153.8	.....	.....	83.1	.018	.057	.....	145.7
			Whole.....	.90	5.7	3.2	20.3	.....	.....	84.2	.134	.476	.....	.....
			Pulp.....	.06	.4	.4	2.7	.....	.....	85.1	.007	.050	.....	.....
			Skin.....	2.70	13.4	8.2	40.6	.....	.....	79.8	.054	.166	.....	.....
			Calyx.....	14.50	78.4	53.2	287.6	.....	.....	81.5	.032	.117	.....	.....
23835	1½ galls. lime-sulphur (32° B.), 50 galls. water. 15 lbs. lead arsenate (powder), 40 lbs. sulphur, 45 lbs. terra alba (dust applications). ¹²	Apr. 28. May 14, June 11, Aug. 9.	Stem ends.....	16.20	102.5	57.2	392.0	.....	.....	84.2	.041	.143	.....	115.9
			Skin.....	2.70	13.4	8.2	40.6	.....	.....	81.5	.032	.117	.....	.....
			Calyx.....	14.50	78.4	53.2	287.6	.....	.....	84.2	.041	.143	.....	.....
			Stem ends.....	16.20	102.5	57.2	392.0	.....	.....	84.2	.041	.143	.....	.....
			Whole.....	.50	3.1	1.5	9.3	.....	.....	85.5	.005	.024	.....	.....
23836	1½ galls. lime-sulphur (32° B.), 50 galls. water. 15 lbs. lead arsenate (powder), 40 lbs. sulphur, 45 lbs. terra alba (dust applications). ¹²	Apr. 28. May 14, June 11, Aug. 9.	Pulp.....	.06	.4	.4	2.7	.....	.....	85.5	.005	.024	.....	.....
			Skin.....	1.50	7.1	4.3	20.4	.....	.....	78.9	.023	.067	.....	.....
			Calyx.....	8.80	46.8	24.2	128.7	.....	.....	81.2	.015	.041	.....	.....
			Stem ends.....	7.50	48.1	21.0	134.6	.....	.....	84.4	.015	.042	.....	.....
			Skin.....	1.50	7.3	4.3	20.4	.....	.....	78.9	.023	.067	.....	.....
23837	1½ galls. lime-sulphur (32° B.), 50 galls. water. 10 lbs. lead arsenate (powder), 60 lbs. barium polysulphid, 30 lbs. terra alba (dust applications). ¹²	Apr. 28. May 14, June 11, Aug. 9.	Calyx.....	8.80	46.8	24.2	128.7	.....	.....	81.2	.015	.041	.....	.....
			Stem ends.....	7.50	48.1	21.0	134.6	.....	.....	84.4	.015	.042	.....	.....
			Whole.....	.33	2.1	.5	3.2	.....	.....	85.3	.010	.032	.....	.....
			Pulp.....	.10	.7	.3	2.0	.....	.....	78.6	.014	.020	.....	.....
			Skin.....	.90	4.2	1.2	5.6	.....	.....	81.0	.008	.007	.....	.....
23838	1½ galls. lime-sulphur (32° B.), 50 galls. water. 10 lbs. lead arsenate (powder), 60 lbs. barium polysulphid, 30 lbs. terra alba (dust applications). ¹²	Apr. 28. May 14, June 11, Aug. 9.	Calyx.....	3.60	18.9	2.2	11.6	.....	.....	84.2	.010	.007	.....	.....
			Stem ends.....	4.00	25.3	2.8	17.7	.....	.....	78.6	.014	.020	.....	.....
			Skin.....	3.60	18.9	2.2	11.6	.....	.....	81.0	.008	.007	.....	.....
			Calyx.....	3.60	18.9	2.2	11.6	.....	.....	78.6	.014	.020	.....	.....
			Stem ends.....	4.00	25.3	2.8	17.7	.....	.....	81.0	.008	.007	.....	.....

TABLE 14.—Arsenic, lead, and copper remaining on sprayed apples at picking time.—Continued.

Sam- ple No.	Spray material used.	Date sprayed.	Determina- tions made on.	Arsenic (As).		Lead (Pb).		Copper (Cu).		Loss on dry- ing.	Arsenic in apple (aver- age).	Lead in apple (aver- age).	Copper in apple (aver- age).	Aver- age weight, apple.	
				Original fruit.	Dried fruit.	Original fruit.	Dried fruit.	Original fruit.	Dried fruit.						
23575 ⁴	2 lbs. lead arsenate (paste), 50 galls. water (first application with Bean Clipper nozzle; Friend mist nozzle, 2 to the rod, on all remaining applications) (200 lbs. pressure). ¹³	1915. May 5-7, 24-26, June 14-15, July 16-17, Aug. 6-9.	Whole.....	3.60	21.7	8.9	53.6			Per ct.	Mg.	Mg.		Grams 142.2	
			Pulp.....	.24	1.5	1.0	6.1			83.4	0.512	1.265			
			Skin.....	20.20	106.9	48.7	257.7			83.7	.029	1.122			
			Calyx.....	46.50	242.2	98.3	512.0			81.1	.341	.823			
			Stem ends.....	36.00	213.0	86.0	508.9			80.8	.074	.157			
			Skin ³	12.80	67.7	30.2	159.8			83.1	.068	.163			
			Calyx ³	46.50	242.0	98.3	512.0			81.1	.216	.510			
23576 ⁴	2 lbs. lead arsenate (paste), 50 galls. water (Vermorel nozzle, 2 nozzles to each 10 ft.; spray rod) (100 lbs. pressure). ¹³	do.....	Stem ends ³	33.30	197.0	81.2	480.5			83.3	.074	.157			
			Whole.....	3.70	21.6	8.9	52.0			82.9	.431	1.036		116.4	
			Pulp.....	.10	6	1.0	6			83.3	.010	.099			
			Skin.....	19.00	96.4	46.0	233.5			80.3	.274	.662			
			Calyx.....	49.00	233.3	97.3	463.3			79.0	.059	.117			
			Stem ends.....	54.80	294.5	98.7	539.3			81.7	.088	.158			
			Skin ³	16.30	82.7	27.5	139.6			80.3	.235	.396			
23577 ⁴	3 lb. com. calcium arsenate (powder), 50 galls. water (first application with Bean Clipper nozzle; Friend mist nozzle, 2 to the rod, on all remaining applications). ¹³	do.....	Calyx ³	40.50	192.9	88.4	421.0			79.0	.049	.106			
			Stem ends ³	54.80	294.5	98.7	539.3			81.7	.088	.158		116.3	
			Whole.....	2.40	15.9					84.9	.279				
			Pulp.....	.36	2.5					85.8	.035				
			Skin.....	6.90	36.7					82.6	.108				
			Calyx.....	39.40	220.1					82.1	.055				
			Stem ends.....	45.20	295.4					84.7	.081				
23578 ⁴ 23579 ⁴	Check plat (unsprayed) ¹³ 4 lbs. lead arsenate (powder) to 250-gal. tank, or 12.8 ozs., 50 galls. water (Bordeaux nozzle, 225 lbs. pressure) (coarse penetrating spray) (rained June 4, 5, 6; so sprayed immediately on June 8). ¹³	May 6, 24, June 3, 8, 17, 29, July 13, 26, Aug. 9, 24.	Skin ³	6.10	35.0					82.6	.095				
			Calyx ³	37.40	208.9					84.7	.081				
			Stem ends ³	45.20	295.4					82.1	.052				
			Whole.....	.32	2.0	1.5	9.3			83.9	.038			118.7	
			Pulp.....do.....	5.00	29.6	12.7	75.1			83.1	.738	1.872		147.5	
			Skin.....	.33	2.0	1.4	8.5			83.5	.041	.173			
			Calyx.....	23.00	114.4	55.1	274.1			79.9	.437	1.047			
23716 ¹⁰	2 lbs. lead arsenate (paste), 50 galls. water (first application with Bean Clipper nozzle; Friend mist nozzle, 2 to the rod, on	May 5-7, 24-26, June 14-15, July 16-17, Aug. 6-9.	Stem ends.....	44.60	212.4	103.6	493.3			79.0	.098	.228			
			Calyx.....	60.00	329.7	157.1	863.2			81.8	.162	.424			
			Skin ³	16.90	84.1	31.0	154.2			79.9	.321	.589			
			Calyx ³	44.60	212.4	103.6	493.3			79.0	.098	.228			
			Stem ends ³	42.50	233.5	86.5	475.3			84.0	.81	.115		165.0	
			Whole.....	4.80	30.0	13.9	86.9			81.8	.792	2.295			
			Pulp.....	.17	1.1	9	6.0			85.1	.023	.119			
Skin.....	18.00	96.8	51.6	263.3			81.4	.363	1.042						

TABLE 14.—Arsenic, lead, and copper remaining on sprayed apples at picking time—Continued.

Sam- ple No.	Spray material used.	Date sprayed.	Determina- tions made on.	Arsenic (As).		Lead (Pb).		Copper (Cu).		Loss on dry- ing.	Arsenic in apple (aver- age).	Lead in apple (aver- age).	Copper in apple (aver- age).	Aver- age weight, apple.
				Orig- inal fruit.	Dried fruit.	Orig- inal fruit.	Dried fruit.	Orig- inal fruit.	Dried fruit.					
				<i>Parts per million.</i>						<i>Pp. ct.</i>	<i>Mg.</i>	<i>Mg.</i>	<i>Mg.</i>	<i>Grams.</i>
25884 ^{1c}	1 lb. lead arsenate (powder), 50 galls. water (coarse nozzle) (12 galls. per tree each application) (18-year-old trees). ¹⁷	1916. Apr. 19, 24, May 3, June 10.	Whole.....	0.50	2.9	1.3	7.6	.....	.....	82.9	0.059	0.153	.....	118.0
			Pulp.....	.10	.6	.5	3.1	.....	.....	84.1	.050	.080	.....	.....
			Skin.....	.50	2.3	2.0	9.4	.....	.....	78.7	.007	.030	.....	.....
			Calyx.....	15.20	74.5	25.3	124.6	.....	.....	79.6	.023	.038	.....	.....
			Stem ends.....	12.80	74.0	23.3	134.7	.....	.....	82.7	.019	.035	.....	.....
			Skin ¹⁶	.50	2.3	2.0	9.4	.....	.....	78.7	.007	.030	.....	.....
			Calyx ¹⁶	8.90	43.6	10.4	51.0	.....	.....	79.6	.013	.016	.....	.....
			Stem ends ¹⁶	12.80	74.0	23.3	134.7	.....	.....	82.7	.019	.035	.....	.....
			Whole.....	.70	4.3	1.9	11.7	.....	.....	83.7	.083	.224	.....	118.0
			Pulp.....	.10	.7	.5	3.4	.....	.....	85.5	.010	.050	.....	.....
25885 ^{1b}	1 lb. lead arsenate (powder), 50 galls. water (fine nozzle) (11 galls. per tree each ap- plication) (18-year-old trees). ¹⁷	Apr. 19, May 3, June 10, July 10.	Whole.....	1.50	7.1	4.8	22.9	.....	.....	79.0	.023	.072	.....	.....
			Pulp.....	9.00	42.5	14.4	67.9	.....	.....	78.8	.013	.021	.....	.....
			Skin.....	25.00	138.1	53.9	297.8	.....	.....	81.9	.037	.081	.....	.....
			Calyx.....	.90	4.3	3.0	14.3	.....	.....	79.0	.013	.045	.....	.....
			Skin ¹⁶	6.70	31.6	9.0	42.5	.....	.....	78.8	.010	.013	.....	.....
			Calyx ¹⁶	15.30	84.5	27.4	151.4	.....	.....	81.9	.023	.041	.....	.....
			Stem ends ¹⁶	.20	1.2	.8	4.6	.....	.....	82.7	.024	.094	.....	118.0
			Whole.....	.03	.2	.3	1.9	.....	.....	84.0	.003	.030	.....	.....
			Pulp.....	.50	2.3	1.5	6.8	.....	.....	77.9	.007	.023	.....	.....
			Skin.....	1.60	7.4	5.6	25.8	.....	.....	78.3	.002	.008	.....	.....
25886 ^{1b}	10 lbs. lead arsenate, 90 lbs. hydrated lime (dust sprayed) (2½ lbs. each applica- tion) (18-year-old trees). ¹⁷	Apr. 17, 30, June 9, July 11.	Whole.....	8.00	42.1	22.3	117.4	.....	.....	81.0	.012	.033	.....	.....
			Pulp.....	.50	2.3	1.5	6.8	.....	.....	77.9	.007	.023	.....	.....
			Skin.....	1.60	7.4	5.6	25.8	.....	.....	78.3	.002	.008	.....	.....
			Calyx.....	8.00	42.1	22.3	117.4	.....	.....	81.0	.012	.033	.....	.....
			Stem ends.....	.05	.3	.3	1.9	.....	.....	83.0	.035	.106	.....	118.0
			Calyx ¹⁶	.30	1.8	.9	5.3	.....	.....	84.4	.005	.030	.....	.....
			Whole.....	.30	1.5	.9	4.4	.....	.....	79.6	.004	.014	.....	.....
			Pulp.....	9.00	45.2	15.8	79.4	.....	.....	80.1	.012	.023	.....	.....
			Skin.....	8.20	48.2	26.1	153.5	.....	.....	79.6	.004	.014	.....	.....
			Calyx.....	.30	1.5	.9	4.4	.....	.....	80.1	.012	.023	.....	.....
25887 ^{1c}	15 lbs. lead arsenate, 85 lbs. hydrated lime (dust sprayed) (2½ lbs. each applica- tion) (18-year-old trees). ¹⁷	do.....	Whole.....	6.20	31.2	8.9	44.7	.....	.....	79.6	.004	.014	.....	.....
			Pulp.....	7.00	41.2	21.4	125.9	.....	.....	83.0	.011	.032	.....	.....
			Skin.....	30	1.8	.9	5.3	.....	.....	83.0	.005	.030	.....	.....
			Calyx.....	.05	.3	.3	1.9	.....	.....	84.5	.005	.030	.....	.....
			Whole.....	.30	1.4	1.0	4.7	.....	.....	78.9	.004	.015	.....	.....
			Pulp.....	7.70	37.2	13.5	65.2	.....	.....	79.3	.011	.020	.....	.....
			Skin.....	10.00	56.2	27.3	153.4	.....	.....	82.2	.015	.041	.....	.....
			Calyx.....	.20	.9	.5	2.4	.....	.....	78.9	.003	.007	.....	.....
			Stem ends.....	2.00	9.7	4.2	20.3	.....	.....	79.3	.003	.006	.....	.....
			Calyx ¹⁶	4.20	36.5	13.8	77.5	.....	.....	82.2	.006	.021	.....	.....
25888 ^{1b}	20 lbs. lead arsenate, 80 lbs. hydrated lime (dust sprayed) (2½ lbs. each application) (18-year-old trees). ¹⁷	do.....	Whole.....	7.00	31.2	8.9	44.7	.....	.....	79.6	.004	.014	.....	.....
			Pulp.....	7.00	41.2	21.4	125.9	.....	.....	83.0	.011	.032	.....	.....
			Skin.....	30	1.8	.9	5.3	.....	.....	83.0	.005	.030	.....	.....
			Calyx.....	.05	.3	.3	1.9	.....	.....	84.5	.005	.030	.....	.....
			Whole.....	.30	1.4	1.0	4.7	.....	.....	78.9	.004	.015	.....	.....
			Pulp.....	7.70	37.2	13.5	65.2	.....	.....	79.3	.011	.020	.....	.....
			Skin.....	10.00	56.2	27.3	153.4	.....	.....	82.2	.015	.041	.....	.....
			Calyx.....	.20	.9	.5	2.4	.....	.....	78.9	.003	.007	.....	.....
			Stem ends.....	2.00	9.7	4.2	20.3	.....	.....	79.3	.003	.006	.....	.....
			Calyx ¹⁶	4.20	36.5	13.8	77.5	.....	.....	82.2	.006	.021	.....	.....

	do.	Who'e.....	4.7	83.0	0.94	118.0
26012 ¹⁰	7½ lbs. calcium arsenate, 92½ lbs. hydrated lime (dust sprayed) (2½ lbs. each application) (15-year-old trees). ¹⁷	Pulp.....	.08	84.3	.....	118.0
		Skin.....	1.90	78.7	.....	135.8
		Calyx.....	13.00	78.9	.....	
		Stem ends.....	25.80	82.0	.....	
		Skin ¹⁶	1.40	78.7	.....	
		Calyx ¹⁶	4.00	78.9	.....	
		Stem ends ¹⁶	19.40	82.0	.....	
		Whole.....	107.8	82.4	.....	
26047 ¹⁰	Check plat (unsprayed) ¹⁷ .	do.....	0.6	3.4	.....	118.0
26286 ¹⁰	50 per cent sulphur, 50 per cent hydrated lime.	Pulp.....	.06	84.0	.....	135.8
		Skin.....	.30	77.8	.....	
		Calyx.....	1.00	77.8	.....	
	May 19, June 12, Aug. 5.	Stem ends.....	3.50	79.4	.....	
		Skin ¹⁶	1.30	83.0	.....	
		Calyx ¹⁶	1.00	77.8	.....	
		Stem ends ¹⁶	3.50	77.8	.....	
		Whole.....	15.8	83.0	.....	
26287 ¹⁰	4 lbs. barium polysulphid, 2 lbs. lead arsenate (paste), 30 galls. water. ¹⁸	Pulp.....	.05	83.9	.....	145.5
		Skin.....	.40	77.2	.....	
		Calyx.....	2.40	80.3	.....	
		Stem ends.....	3.20	83.0	.....	
		Skin ¹⁶	2.40	77.2	.....	
		Calyx ¹⁶	2.40	80.3	.....	
		Stem ends ¹⁶	3.20	83.0	.....	
		Whole.....	18.8	81.8	.....	
26288 ¹⁰	1½ lbs. soluble sulphur, 50 galls. water. ¹⁸	do.....	.04	82.1	.....	138.0
26289 ¹⁰	1 lb. soluble sulphur, 50 galls. water. ¹⁸	do.....	.20	83.9	.....	143.0
26420 ¹⁰	Commercial mixture of 50 per cent sulphur, 50 per cent lead arsenate (dust application, 1 lb. per tree). ¹⁸	Pulp.....	.10	84.3	.....	131.7
		Skin.....	.70	78.4	.....	
		Calyx.....	31.1	80.7	.....	
		Stem ends.....	13.00	83.2	.....	
		Skin ¹⁶	50	78.4	.....	
		Calyx ¹⁶	6.00	80.7	.....	
		Stem ends ¹⁶	13.00	83.2	.....	
26421 ¹⁰	1½ galls. lime-sulphur, 50 galls. water..... 1½ galls. lime-sulphur, 1 lb. lead arsenate (powder), 50 galls. water. ¹⁸	Whole.....	30	83.7	.....	130.3
		Pulp.....	1.8	84.7	.....	
		Skin.....	3.6	77.7	.....	
		Calyx.....	2.90	77.7	.....	
		Stem ends.....	6.60	83.1	.....	
		Skin ¹⁶	2.90	77.7	.....	
		Calyx ¹⁶	3.00	83.1	.....	
		Stem ends ¹⁶	3.00	83.7	.....	
26422 ¹⁰	1½ galls. lime-sulphur, 50 galls. water..... 1½ galls. lime-sulphur, 50 galls. water, ¼ lb. arsenate of lime (powder). ¹⁸	Whole.....	20	83.7	.....	133.8
		Pulp.....	1.6	84.5	.....	
		Skin.....	1.40	78.5	.....	
		Calyx.....	1.50	80.7	.....	
		Stem ends.....	2.40	83.2	.....	
		Skin ¹⁶	3.0	78.5	.....	
		Calyx ¹⁶	1.50	80.7	.....	
		Stem ends ¹⁶	1.60	83.2	.....	

For footnote references see page 47.

TABLE 14.—*Arsenic, lead, and copper remaining on sprayed apples at picking time—Continued.*

Sam- ple No.	Spray material used.	Date sprayed.	Determina- tions made on.	Arsenic (As)		Lead (Pb).		Copper (Cu.)		Loss on dry- ing.	Arsenic in apple (aver- age).	Lead in apple (aver- age).	Copper in apple (aver- age).	Aver- age weight, apple.
				Original fruit.	Dried fruit.	Original fruit.	Dried fruit.	Original fruit.	Dried fruit.					
<i>Parts per million.</i>														
26540 ¹⁰	65 per cent sulphur, 35 per cent hydrated lime. 60 per cent sulphur, 32.5 per cent hydrated lime, 7.5 per cent arsenate of lime (dust application). ¹⁶	May 9. May 19, June 12, Aug. 5.	Whole.....	0.10	0.6					<i>Per ct.</i>	<i>Mg.</i>	<i>Mg.</i>		<i>Grams.</i>
			Pulp.....	.07	.4					82.1	0.013			129.7
			Skin.....	.20	.9					83.3	.007			
			Calyx.....	1.70	8.1					77.6	.003			
			Stem ends.....	.90	5.1					79.0	.002			
			Skin ¹⁶	.20	.9					82.2	.001			
		May 10. May 20, June 13, Aug. 6.	Calyx ¹⁶	1.70	8.1					79.0	.002			
			Stem ends ¹⁶	.90	5.1					82.2	.001			
			Whole.....	.30	1.8					83.8	.037	0.126		125.6
			Pulp.....	.00	.7					84.7	.010	.031		
26541 ¹⁰	14 galls. lime-sulphur (32° B.), 50 galls. water. 14 galls. lime-sulphur (32° B.), 50 galls. water, 1 lb. lead arsenate (powder). ¹⁸	May 9. May 19, June 12, Aug. 5.	Skin.....	.80	3.7					78.5	.014	.043		
			Calyx.....	2.30	12.0					80.9	.003	.010		
			Stem ends.....	6.40	39.3					83.7	.010	.042		
			Skin ¹⁶	.80	3.7					78.5	.014	.043		
			Calyx ¹⁶	2.30	12.0					80.9	.003	.010		
			Skin ends ¹⁶	4.80	29.4					83.7	.007	.034		
		May 10. May 19, June 12, Aug. 5.	Whole.....	.40	2.5					84.1	.047	.130		118.3
			Pulp.....	.10	.7					85.3	.010	.030		
			Skin.....	.50	2.5					79.8	.008	.024		
			Calyx.....	10.80	59.0					81.7	.012	.024		
26640 ¹⁰	80 per cent sulphur, 20 per cent lead arsenate (dust applications) (about 1 lb. per tree each application) (15-year-old trees). ¹⁸	May 9, 19, June 12, Aug. 5.	Stem ends.....	15.00	88.2					83.0	.017	.052		
			Skin ¹⁹	.50	2.5					79.8	.008	.024		
			Calyx ⁹	6.40	35.0					81.7	.006	.018		
			Stem ends ¹⁹	10.60	62.4					83.0	.012	.032		124.2
			Whole.....	.30	1.8					83.6	.037	.124		
			Pulp.....	.07	.4					84.2	.007	.032		
		May 9, 19, June 12, Aug. 5.	Skin.....	.30	1.4					78.6	.005	.029		
			Calyx.....	12.00	59.1					79.7	.012	.030		
			Stem ends.....	11.60	65.5					82.3	.013	.033		
			Skin ¹⁹	.30	1.4					78.6	.005	.029		
26652 ¹⁰	1 lb. com. Bordeaux (10 per cent Cu), 50 galls. water. ¹⁸	May 10, 19, June 13, Aug. 6.	Calyx ¹⁹	6.40	31.5					79.7	.006	.016		
			Stem ends ¹⁹	7.90	44.6					82.3	.009	.026		
			Whole.....							82.1				133.3
			Pulp.....							83.5				
			Skin.....							77.7				
			Calyx.....							78.4				
		May 10, 19, June 13, Aug. 6.	Stem ends.....							81.1				
			Skin ¹⁹							77.7				
			Calyx ¹⁹							8.5				
			Stem ends ¹⁹							25.0				

2663310	5 lbs. com. powder (12½ per cent Cu, 3 per cent As), 50 galls. water. ¹⁵	May 10, 20, June 13, Aug. 6.	Whole..... Pulp..... Skin..... Calyx..... Stem ends..... Skin ¹⁹ Skin ¹⁹ Stem ends ¹⁹ Whole..... Pulp..... Skin..... Calyx..... Stem ends..... Skin ¹⁹ Skin ¹⁹ Stem ends ¹⁹	12 .07 20 1.00 3.60 1.00 2.00 3.60 2.60 .08 20 9.00 2.00 2.70 5.70	7 4 9 4.8 19.9 4.8 4.8 1.2 1.0 5 1.0 20.0 51.1 1.0 13.5 32.4	7 4 9 4.8 19.9 4.8 4.8 1.2 1.0 5 1.0 20.0 51.1 1.0 13.5 32.4	82.2 83.6 77.5 79.3 81.9 77.5 81.9 83.8 79.5 80.0 82.4 79.5 80.0 82.4 83.1 83.2	3.9 3.0 4.4 31.9 66.9 4.4 15.0 58.6	.097 .059 .018 .006 .014 .018 .003 .013	135.2
2670210	65 per cent sulphur, 35 per cent hydrated lime. 65 per cent sulphur, 25 per cent hydrated lime, 10 per cent lead arsenate (dust application), 1.9 lbs. per tree each application) (15-year-old trees). ¹⁵	May 9. May 19, June 12, Aug. 5.	Whole..... Pulp..... Skin..... Calyx..... Stem ends..... Skin ¹⁹ Skin ¹⁹ Stem ends ¹⁹	12 .08 20 9.00 2.00 2.70 5.70	7 4 9 4.8 19.9 4.8 4.8 1.2	7 4 9 4.8 19.9 4.8 4.8 1.2	82.2 83.6 77.5 79.3 81.9 77.5 81.9 83.8	3.9 3.0 4.4 31.9 66.9 4.4 15.0 58.6	.097 .059 .018 .006 .014 .018 .003 .013	116.0
2670310	Check plat (unsprayed). ¹⁵	May 10, 20, June 13, Aug. 6.	Whole..... Pulp..... Skin..... Calyx..... Stem ends..... Skin ¹⁹ Skin ¹⁹ Stem ends ¹⁹	12 .09 20 9.00 2.00 2.70 5.70	7 4 9 4.8 19.9 4.8 4.8 1.2	7 4 9 4.8 19.9 4.8 4.8 1.2	82.2 83.6 77.5 79.3 81.9 77.5 81.9 83.8	3.9 3.0 4.4 31.9 66.9 4.4 15.0 58.6	.097 .059 .018 .006 .014 .018 .003 .013	123.8 137.2
2670410	1 pt. com. preparation (6.3 per cent lead arsenate, 8 per cent Paris green), 50 galls. water. ¹⁵	May 10, 20, June 13, Aug. 6.	Whole..... Pulp..... Skin..... Calyx..... Stem ends..... Skin ¹⁹ Skin ¹⁹ Stem ends ¹⁹	12 .12 20 9.00 2.00 2.70 5.70	7 4 9 4.8 19.9 4.8 4.8 1.2	7 4 9 4.8 19.9 4.8 4.8 1.2	82.2 83.6 77.5 79.3 81.9 77.5 81.9 83.8	3.9 3.0 4.4 31.9 66.9 4.4 15.0 58.6	.097 .059 .018 .006 .014 .018 .003 .013	137.2
2671910	1 lb. lead arsenate (powder), 50 galls. water (pressure, 225 lbs.). 1 lb. lead arsenate (powder), 50 galls. water (Bordeaux nozzle, very coarse spray, all applications) (pressure, 200 lbs.). ²⁰	May 2. May 29, July 8, Aug. 18.	Whole..... Pulp..... Skin..... Calyx..... Stem ends..... Skin ¹⁹ Skin ¹⁹ Stem ends ¹⁹	12 .04 20 9.00 2.00 2.70 5.70	7 4 9 4.8 19.9 4.8 4.8 1.2	7 4 9 4.8 19.9 4.8 4.8 1.2	82.2 83.6 77.5 79.3 81.9 77.5 81.9 83.8	3.9 3.0 4.4 31.9 66.9 4.4 15.0 58.6	.097 .059 .018 .006 .014 .018 .003 .013	157.3
2672010	1 lb. lead arsenate (powder), 50 galls. water (Bordeaux nozzle, very coarse spray) (pressure, 225 lbs.). 1 lb. lead arsenate (powder), 50 galls. water (Bordeaux nozzle, very coarse spray) (pressure, 225 lbs.). 1 lb. lead arsenate (powder), 50 galls. water (Friend nozzle, mist-like spray) (pressure, 200 lbs.). ²⁰	May 2. May 29, July 8, Aug. 18.	Whole..... Pulp..... Skin..... Calyx..... Stem ends..... Skin ¹⁹ Skin ¹⁹ Stem ends ¹⁹	12 .05 20 9.00 2.00 2.70 5.70	7 4 9 4.8 19.9 4.8 4.8 1.2	7 4 9 4.8 19.9 4.8 4.8 1.2	82.2 83.6 77.5 79.3 81.9 77.5 81.9 83.8	3.9 3.0 4.4 31.9 66.9 4.4 15.0 58.6	.097 .059 .018 .006 .014 .018 .003 .013	148.5
2675810	1 lb. lead arsenate (powder), 50 galls. water (pressure, 225 lbs.). 1 lb. lead arsenate (powder), 50 galls. water (Bordeaux nozzle, very coarse spray, all applications) (pressure, 200 lbs.). ²⁰	May 2. May 29, June 16, July 8, Aug. 18.	Whole..... Pulp..... Skin..... Calyx..... Stem ends..... Skin ¹⁹ Skin ¹⁹ Stem ends ¹⁹	12 .06 20 9.00 2.00 2.70 5.70	7 4 9 4.8 19.9 4.8 4.8 1.2	7 4 9 4.8 19.9 4.8 4.8 1.2	82.2 83.6 77.5 79.3 81.9 77.5 81.9 83.8	3.9 3.0 4.4 31.9 66.9 4.4 15.0 58.6	.097 .059 .018 .006 .014 .018 .003 .013	152.8

For footnote references see page 47.

TABLE 14.—Arsenic, lead, and copper remaining on sprayed apples at picking time—Continued.

Sam- ple No.	Spray material used.	Date sprayed.	Determina- tions made on.	Arsenic (As).		Lead (Pb).		Copper (Cu).		Loss on dry- ing.	Arsenic in apple (aver- age).	Lead in apple (aver- age).	Copper in apple (aver- age).	Aver- age weight, apple.			
				Orig- inal fruit.	Dried fruit.	Orig- inal fruit.	Dried fruit.	Orig- inal fruit.	Dried fruit.								
				<i>Parts per million.</i>										<i>Per ct.</i>	<i>Mg.</i>	<i>Mg.</i>	<i>Grams.</i>
26963 ¹⁰	1 lb. lead arsenate (powder), 50 galls. water (Bordeaux nozzle, very coarse spray) (pressure, 225 lbs.). 1 lb. lead arsenate (powder), 50 galls. water (friend nozzle, mist-like spray) (pres- sure, 200 lbs.). ²⁰	May 2.	Whole.....	1.40	9.3	4.7	31.3			85.0	0.216	0.725			154.4		
			Pulp.....	.04	3	.5	3.5	.....	.....	85.9	.005	.066	.....	.....			
		May 29, June 16, July 8, Aug. 18.	Skin.....	4.40	25.3	15.1	86.8	.....	.....	82.6	.088	.302	.....	.....			
			Calyx.....	46.50	256.9	137.6	760.2	.....	.....	81.9	.051	.151	.....	.....			
			Stem ends.....	59.80	366.9	172.0	1,055.2	.....	.....	83.7	.072	.206	.....	.....			
			Skin ¹⁹	3.40	19.5	10.2	58.6	.....	.....	82.6	.068	.204	.....	.....			
			Calyx ¹⁹	19.20	106.1	78.7	434.8	.....	.....	81.9	.087	.021	.....	.....			
			Stem ends ¹⁹	59.80	366.9	172.0	1,055.2	.....	.....	83.7	.072	.206	.....	.....			
		May 2.	Whole.....	1.40	9.3	4.8	32.0			85.0	.212	.729			151.8		
		27073 ¹⁰	1 lb. lead arsenate (powder), 50 galls. water (pressure, 225 lbs.). 1 lb. lead arsenate (powder), 50 galls. water (Bordeaux nozzle, very coarse spray, all applications) (pressure, 200 lbs.). ²⁰	May 2.	Pulp.....	.03	2	.5	3.4			85.3	.004	.064			
Skin.....	5.60				30.8	17.6	96.7	.....	.....	81.8	.112	.352	.....	.....			
May 29, June 12, 26, July 8, Aug. 18.	Calyx.....			42.00	214.3	137.3	700.5	.....	.....	80.4	.050	.151	.....	.....			
	Stem ends.....			41.70	230.4	135.5	748.6	.....	.....	81.9	.057	.162	.....	.....			
	Skin ¹⁹			2.30	12.6	7.9	41.8	.....	.....	80.8	.047	.151	.....	.....			
	Calyx ¹⁹			42.00	214.3	137.3	700.5	.....	.....	80.8	.046	.151	.....	.....			
	Skin ¹⁹			34.10	188.4	112.1	619.3	.....	.....	81.9	.041	.133	.....	.....			
	Stem ends ¹⁹			1.80	12.2	6.1	41.2	.....	.....	83.2	.295	1.000	.....	.....			
May 2.	Whole.....			.10	7	.5	3.5	.....	.....	85.8	.014	.070	.....	.....			
26725 ¹⁰	1 lb. lead arsenate (powder), 50 galls. water (Bordeaux nozzle, very coarse spray) (pressure, 225 lbs.). 1 lb. lead arsenate (powder), 50 galls. water (friend nozzle, mist-like spray) (pres- sure, 200 lbs.). ²⁰			May 29, June 12, 26, July 8, Aug. 18.	Pulp.....	6.70	38.3	24.4	139.4			82.5	.137	.537			
		Skin.....	43.30		231.5	124.6	666.3	.....	.....	81.3	.052	.149	.....	.....			
		May 29, June 12, 26, July 8, Aug. 18.	Calyx.....	63.60	392.6	187.5	1157.4	.....	.....	83.8	.244	.852	.....	.....			
			Stem ends.....	2.60	14.9	10.5	60.0	.....	.....	82.5	.037	.231	.....	.....			
			Skin ¹⁹	37.50	200.5	93.8	501.6	.....	.....	81.3	.045	.112	.....	.....			
			Calyx ¹⁹	63.60	392.6	187.5	1157.4	.....	.....	83.8	.244	.852	.....	.....			
		May 6, June 2, July 8.	Stem ends ¹⁹	.02	.6	.7	4.2	.....	.....	83.4	.014	.100	.....	.....			
			Whole.....	.10	.6	.7	4.2	.....	.....	84.4	.002	.048	.....	.....			
			Pulp.....	.15	.8	1.0	5.3	.....	.....	81.0	.003	.019	.....	.....			
			Skin.....	3.10	14.1	10.4	47.3	.....	.....	78.0	.003	.010	.....	.....			
26730 ¹⁰	10 per cent lead arsenate, 90 per cent terra alba (dust applications). ²⁰	May 29, June 12, 26, July 8, Aug. 18.	Calyx.....	5.00	29.1	19.0	110.5	.....	.....	82.8	.006	.023	.....	.....			
			Stem ends.....	.15	.8	1.0	5.3	.....	.....	81.0	.003	.019	.....	.....			
		May 29, June 12, 26, July 8, Aug. 18.	Skin ¹⁹	3.10	14.1	10.4	47.3	.....	.....	78.0	.003	.010	.....	.....			
			Calyx ¹⁹	5.00	29.1	19.0	110.5	.....	.....	82.8	.006	.023	.....	.....			
			Stem ends ¹⁹	.08	.30	2.0	7.9	.....	.....	84.8	.045	.180	.....	.....			
			Whole.....	.08	.30	2.0	7.9	.....	.....	85.0	.010	.051	.....	.....			
		May 6, June 2, July 8, Aug. 18.	Pulp.....	1.30	7.1	3.9	21.2	.....	.....	81.2	.026	.078	.....	.....			
			Skin.....	4.20	20.0	20.5	97.6	.....	.....	79.0	.004	.023	.....	.....			
			Calyx.....	4.70	27.0	23.4	134.5	.....	.....	82.6	.005	.028	.....	.....			
			Stem ends.....	.60	3.3	2.1	11.4	.....	.....	81.6	.012	.042	.....	.....			
26739 ¹⁰	10 per cent lead arsenate, 90 per cent terra alba (dust applications). ²⁰	May 29, June 12, 26, July 8, Aug. 18.	Calyx ¹⁹	2.20	10.5	12.5	59.5	.....	.....	79.0	.002	.014	.....	.....			
			Stem ends ¹⁹	4.70	27.0	23.4	134.5	.....	.....	82.6	.005	.028	.....	.....			
		May 29, June 12, 26, July 8, Aug. 18.	Whole.....	.08	.30	2.0	7.9	.....	.....	82.6	.005	.028	.....	.....			
			Pulp.....	.08	.30	2.0	7.9	.....	.....	82.6	.005	.028	.....	.....			
			May 6, June 2, July 8, Aug. 18.	Skin.....	1.30	7.1	3.9	21.2			81.0	.003	.010				
				Calyx.....	4.20	20.0	20.5	97.6			79.0	.004	.023				
		Stem ends.....		4.70	27.0	23.4	134.5	.....	.....	82.6	.005	.028	.....	.....			
		Skin ¹⁹		.60	3.3	2.1	11.4	.....	.....	81.6	.012	.042	.....	.....			
		May 6, June 2, July 8, Aug. 18.	Calyx ¹⁹	2.20	10.5	12.5	59.5	.....	.....	79.0	.002	.014	.....	.....			
			Stem ends ¹⁹	4.70	27.0	23.4	134.5	.....	.....	82.6	.005	.028	.....	.....			

26968 ¹⁰	10 per cent lead arsenate, 90 per cent terra alba (dust applications). ²⁰	May 6, June 2, 20, July 8, Aug. 18.	Whole..... Pulp..... Skin..... Calyx..... Stem ends..... Skin ¹⁹ Calyx ¹⁹ Stem ends ¹⁹	1.8 .6 5.2 21.4 5.00 1.00 3.50 5.00	1.2 .5 3.3 19.0 24.2 3.3 14.5 24.2	7.2 3.1 17.1 84.8 132.2 17.1 64.7 24.0	83.4 84.0 84.0 77.6 81.7 80.7 77.6 81.7	.041 .058 .063 .019 .024 .063 .015 .004	136.9
26726 ¹⁰	20 per cent lead arsenate, 80 per cent terra alba (dust applications). ²⁰	May 6, June 2, July 8, Aug. 18.	Whole..... Pulp..... Skin..... Calyx..... Stem ends..... Skin ¹⁹ Calyx ¹⁹ Stem ends ¹⁹	3.0 1.8 5.8 27.3 5.00 1.8 3.5 23.9	1.3 3.5 3.4 26.0 23.9 1.3 3.2 23.9	8.0 17.9 118.2 128.5 90.9 128.5 3.4	83.8 84.4 81.0 81.0 78.0 81.4 85.5	.004 .004 .004 .007 .024 .005 .004 .006	129.3
26727 ¹⁰	Check plat (unsprayed). ²⁰	1917.	Whole.....	.04	.5	3.4	81.4	.074	148.9
28431 ²¹	14 galls. lime-sulphur, 50 galls. water, 2 lbs. lead arsenate (paste).	Apr. 14, 26, May 17.	Whole..... Pulp..... Skin..... Calyx..... Stem ends..... Skin ¹⁹ Calyx ¹⁹ Stem ends ¹⁹	.05 .02 1.0 2.80 3.8 1.0 1.90 3.8	.7 .4 1.2 18.5 6.2 1.2 11.3 6.2	4.6 2.8 6.2 96.4 38.8 6.2 58.9 38.8	84.7 85.6 80.8 84.0 80.5 80.8 81.0 85.0	.007 .002 .048 .002 .018 .009 .002 .011 .009 .100	143.0
28432 ²¹	14 galls. lime-sulphur, 50 galls. water, 2 lbs. lead arsenate (paste). ²²	Apr. 14, 26, May 17.	Whole.....	.03	.2	4.6	85.0	.071	143.0
29096 ¹⁰	Check plat (unsprayed). ²⁴	May 26.	Whole.....	.09	.5	2.2	81.9	.008	94.3
29097 ¹⁰	1 lb. lead arsenate (powder), 50 galls. water (Bean Clipper nozzle).	June 13, 28, July 19, Aug. 24.	Whole..... Pulp..... Skin..... Calyx..... Stem ends..... Skin ¹⁹ Calyx ¹⁹ Stem ends ¹⁹	1.40 .08 3.80 52.50 17.00 30 19.70 12.30	4.5 .5 12.2 154.0 51.0 3.9 52.6 29.2	26.9 3.2 61.6 762.4 291.4 19.7 260.4 166.9	83.3 84.2 80.2 82.5 79.8 80.2 82.5 82.5	.332 .039 .056 .181 .154 .051 .058 .029	94.6
29098 ¹⁰	1 lb. lead arsenate (powder), 50 galls. water (Bean Clipper nozzle).	May 26.	Whole.....	3.00	1.3	3.1	84.0	.014	89.5
	1 lb. lead arsenate (powder), 50 galls. water (Friend Whirlpool mist nozzle). ²³	June 13, 23, July 4, 19, Aug. 14, Sept. 4.	Whole..... Pulp..... Skin..... Calyx..... Stem ends..... Skin ¹⁹ Calyx ¹⁹ Stem ends ¹⁹	11.00 54.5 243.4 53.30 40.20 7.9 16.80 15.80	30.6 151.5 161.1 121.6 2.9 52.1 76.7 48.8	151.5 735.6 633.8 14.4 237.9 262.4	79.8 78.1 81.4 79.8 78.1 81.4	.016 .036 .162 .161 .040 .024 .043 .017 .049	

For footnote references see page 47.

TABLE 14.—*Arsenic, lead, and copper remaining on sprayed apples at picking time—Continued.*

Sim- ple No.	Spray material used.	Date sprayed.	Determi- nations made on.	Arsenic (As).		Lead (Pb).		Copper (Cu).		Loss on dry- ing.	Arsenic in apple (aver- age).	Lead in apple (aver- age).	Copper in apple (aver- age).	Aver- age weight, apple.
				Orig- inal fruit.	Dried fruit.	Orig- inal fruit.	Dried fruit.	Orig- inal fruit.	Dried fruit.					
				Parts per million.										
29099 ¹⁰	1 lb. lead arsenate (powder), 50 galls. water (Friend Whirpool mist nozzle). ²³	1917. June 13, 23, July 4, 19, Aug. 23.	Whole.....	1.90	10.6	6.1	33.9			82.0	Mg.	0.547		80.8
			Pulp.....	1.08	5	2.9			83.0		0.086			
			Skin.....	7.70	35.8	23.0	107.0			78.5		0.114		
			Calyx.....	21.90	95.2	68.6	298.3			77.0		0.069		
			Stem ends.....	29.50	159.4	102.2	552.4			81.5		0.102		
			Skin ¹⁹	1.70	7.9	4.8	22.3			78.5		0.071		
			Calyx ¹⁹	12.50	54.3	29.5	128.3			77.0		0.030		
			Stem ends ¹⁹	17.70	95.7	53.5	289.2			81.5		0.018		
33375	1 lb. lead arsenate (powder), 3 lbs. atomic sulphur, 50 galls. water (pressure, 225- 250 lbs.). ²⁴	1919. May 8-10.	Whole.....	1.40	9.6	5.2	36.0			85.4		0.810		154.0
			Pulp.....	0.05	4	7	3.3			86.6		0.063		
			Skin.....	6.60	34.0	30.0	160.0			80.9		0.110		
			Calyx.....	34.00	170.0	93.0	480.0			80.5		0.052		
			Stem ends.....	24.00	140.0	81.0	470.0			82.6		0.034		
			Skin ³	3.10	16.0	13.0	68.0			80.5		0.049		
			Calyx ³	23.00	120.0	66.0	330.0			79.9		0.040		
			Stem ends ³	11.00	66.0	39.0	230.0			82.9		0.018		
33376	2 lb. calcium arsenate (powder), 2 lbs. lime, 2 lbs. flour, 50 galls. water (pres- sure, 200-225 lbs.). ²⁴	May 29-31, June 18-20, July 21-24, Aug. 18-21. May 8-10.	Whole.....	7.9	6.2				87.3		0.130		183.0	
			Pulp.....	0.07						88.0		0.010		
			Skin.....	5.80	35.0					83.4		0.110		
			Calyx.....	24.00	140.0					81.9		0.031		
			Stem ends.....	27.00	170.0					83.5		0.033		
			Skin ³	1.10	6.5					82.8		0.024		
			Calyx ³	16.00	91.0					82.2		0.022		
			Stem ends ³	17.00	102.0					83.4		0.017		
33377	1 lb. lead arsenate (powder), 3 lbs. atomic sulphur, 50 galls. water, Spreader No. 1 ²⁵ (pressure, 225-240 lbs.). ²⁴	May 8-10. May 29-31.	Whole.....	1.20	9.5	3.3	26.0			87.4		0.800		240.0
			Pulp.....	0.07		6	6.0			89.0		0.008		
			Skin.....	8.80	54.0	26.0	160.0			83.6		0.170		
			Calyx.....	35.00	220.0	104.0	630.0			83.6		0.041		
			Stem ends.....	44.00	300.0	115.0	790.0			85.2		0.039		
			Skin ³	1.80	11.0	2.7	16.0			83.2		0.038		
			Calyx ³	10.00	65.0	35.0	220.0			83.9		0.041		
			Stem ends ³	9.30	62.0	24.0	160.0			85.1		0.009		
33378	1 lb. lead arsenate (powder), 50 galls. water, Spreader No. 2 (pressure, 225 lbs.). ²⁶	June 18-20, July 21-24, Aug. 18-21. May 8-10.	Whole.....	5.40	40.0	17.0	130.0			86.5		2.800		166.0
			Pulp.....	0.08		1.8	15.0			87.4		0.010		
			Skin.....	22.00	130.0	75.0	430.0			82.7		1.500		
			Whole.....	5.40	40.0	17.0	130.0			86.5		2.800		166.0
			Pulp.....	0.08		1.8	15.0			87.4		0.010		
			Skin.....	22.00	130.0	75.0	430.0			82.7		1.500		
			Whole.....	5.40	40.0	17.0	130.0			86.5		2.800		166.0
			Pulp.....	0.08		1.8	15.0			87.4		0.010		

33379	3 lbs. lead arsenate (powder), 50 galls. water (pressure, 225 lbs.). ²⁴	May 29-31, June 18-20, July 21-24, Aug. 18-21.	Calyx..... Stem ends..... Skin..... Calyx..... Stem ends..... Whole..... Pulp..... Skin..... Calyx..... Stem ends..... Skin..... Stem ends..... Whole..... Pulp..... Skin..... Calyx..... Stem ends.....	127.00 328.00 7.60 83.00 68.00 3.70 .11 15.00 49.00 210.00 5.00 24.00 76.00 .56 3.50 21.00 13.00 2.60 21.00 8.00	760.0 2000.0 44.0 470.0 390.0 26.0 91.0 300.0 1700.0 31.0 150.0 600.0 4.4 21.0 130.0 87.0 16.0 130.0 60.0	328.0 421.0 28.0 297.0 1700.0 252.0 1.4 80.0 120.0 550.0 61.0 13.0 190.0 4 21.0 130.0 16.0 380.0 1500.0	2000.0 2500.0 160.0 1700.0 1500.0 110.0 11.0 480.0 750.0 4400.0 32.0 380.0 1500.0 4 21.0 130.0 16.0 380.0 1500.0	83.3 82.9 83.0 83.1 82.6 86.1 87.6 83.6 83.8 87.6 83.7 84.3 87.5 88.2 82.8 84.9 83.4 84.6 83.9	.150 .310 .140 .530 .230 .058 .580 .014 .310 .068 .240 .630 .100 .030 .075 .180 .008 .073 .028 .016 .058 .028 .012	159.0
33380	1½ lbs. magnesium arsenate (powder), 50 galls. water (pressure, 225-250 lbs.). ²⁴ 1½ lbs. magnesium arsenate (powder), 50 galls. water (pressure, 225 lbs.). ²⁴	May 8-10. May 29-31, June 18-20, July 21- 24, Aug. 18-21.	Calyx..... Stem ends..... Skin..... Calyx..... Stem ends..... Whole..... Pulp..... Skin..... Calyx..... Stem ends..... Skin..... Stem ends..... Whole..... Pulp..... Skin..... Calyx..... Stem ends.....	127.00 328.00 7.60 83.00 68.00 3.70 .11 15.00 49.00 210.00 5.00 24.00 76.00 .56 3.50 21.00 13.00 2.60 21.00 8.00	760.0 2000.0 44.0 470.0 390.0 26.0 91.0 300.0 1700.0 31.0 150.0 600.0 4.4 21.0 130.0 87.0 16.0 130.0 60.0	328.0 421.0 28.0 297.0 1700.0 252.0 1.4 80.0 120.0 550.0 61.0 13.0 190.0 4 21.0 130.0 16.0 380.0 1500.0	2000.0 2500.0 160.0 1700.0 1500.0 110.0 11.0 480.0 750.0 4400.0 32.0 380.0 1500.0 4 21.0 130.0 16.0 380.0 1500.0	83.3 82.9 83.0 83.1 82.6 86.1 87.6 83.6 83.8 87.6 83.7 84.3 87.5 88.2 82.8 84.9 83.4 84.6 83.9	.150 .310 .140 .530 .230 .058 .580 .014 .310 .068 .240 .630 .100 .030 .075 .180 .008 .073 .028 .016 .058 .028 .012	179.0

¹ Rome Beauty.² Harvested last of October, 1915, Moorestown, N. J.³ Fruit wiped with dry cloth before peeling.⁴ Jonathan.⁵ Harvested Aug. 26, 1915, Rosewell, N. Mex.⁶ Harvested Sept. 1, 1915, Rosewell, N. Mex.⁷ Harvested Sept. 10, 1915, Rosewell, N. Mex.⁸ Winesap.⁹ Harvested Sept. 20, 1915, Rosewell, N. Mex.¹⁰ Ben Davis.¹¹ Harvested Oct. 16, 1915, Rosewell, N. Mex.¹² Harvested Oct. 28, 1915, Benton Harbor, Mich.¹³ Harvested Oct. 10, 1915, Grand Junction, Colo.¹⁴ Harvested last of October, 1915, Grand Junction, Colo.¹⁵ Harvested Oct. 22, 1916, Moorestown, N. J.¹⁶ Fruit wiped with damp cloth before peeling.¹⁷ Harvested Oct. 2, 1916, Rosewell, N. Mex.¹⁸ Harvested Oct. 28, 1916, Benton Harbor, Mich.¹⁹ Fruit washed under tap water and wiped with dry towel before peeling.²⁰ Harvested Nov. 1, 1916, Grand Junction, Colo.²¹ Albemarle Pippin.²² Harvested Sept. 14, 1917, Greenwood, Va.²³ Harvested Oct. 29, 1917, Grand Junction, Colo.²⁴ Harvested Oct. 15, 1919, Yakima, Wash.²⁵ Spreaders 1 made by thoroughly mixing 1½ parts of casein with 3½ parts of hydrated lime, 12 ounces of the mixture being worked into a paste with water and added to 200 gallons of spray mixture.²⁶ Spreaders 2 made by thoroughly mixing 1½ ounces of borax with 10 ounces of casein, the mixture thoroughly agitated with water, and used at the rate of half of this amount to a 200-gallon tank of spray mixture.

Several spray schedules are represented by the samples shown in Table 14. Very little spray residue was present on the apples, except Samples 23598, 33378, and 33379, which were purposely heavily sprayed, and the apples from Grand Junction, Colo. The 1915 samples from Grand Junction showed so much more residue than the apples from other districts that the spraying schedule was changed in 1916 and 1917, with the result that much less spray residue was found on the fruit.

TABLE 15.—*Arsenic, lead, and copper remaining on fruits and vegetables sprayed with poisonous sprays (summary).*

Product.	Determinations made on.	Arsenic (As).				Lead (Pb).				Copper (Cu).			
		Original basis.		Dry basis.		Original basis.		Dry basis.		Original basis.		Dry basis.	
Parts per million.													
Peaches:													
Sprayed.....	Whole.....	0.02	0.94	0.10	8.0	0.3	2.6	2.0	23.0				
	Pulp.....	.00	.14	.00	1.2	.1	.8	.7	5.6				
	Skin.....	.04	4.50	.20	35.4	.7	12.2	4.4	96.1				
Unsprayed.....	Whole.....	.00	.23	.00	2.0	.0	.6	.0	4.0				
	Pulp.....	.00	.10	.00	.9	.0	.4	.0	2.8				
	Skin.....	.00	.77	.00	6.1	.0	1.7	.0	11.9				
Cherries:													
Sprayed.....	Whole.....	.04	.35	.20	2.3	.6	1.3	2.8	8.1	2.0	3.2	11.9	15.2
	Whole ¹	.02	.17	.10	1.1	.4	1.3	1.9	8.1	1.2	1.8	7.9	10.6
Unsprayed.....	Whole.....	.02	.08	.16	.6	.6	.7	2.8	5.3	.5	1.4	4.0	8.3
Plums:													
Sprayed.....	Whole.....	.03	.13	.20	.8	.2	.5	1.6	3.1	.3	1.2	2.4	6.8
	Whole ¹	.02	.10	.20	.6	.2	.5	1.5	2.9	.3	.9	2.4	5.1
Unsprayed.....	Whole.....	.03	.10	.20	.6	.3	.4	2.2	2.3	.5	.6	3.4	3.7
	Whole ¹	.02	.07	.10	.4	.2	.3	1.4	1.7	.4	.6	3.0	3.4
Tomatoes:													
Sprayed.....	Whole.....	.07	.30	1.10	5.2	.5	1.7	7.6	29.8	.8	5.7	14.3	91.9
	Pulp.....	.02	.05	.30	.9	.2	1.2	3.3	21.1	.5	2.2	9.4	35.5
Unsprayed.....	Whole.....	.02	.07	.40	1.4	.3	.9	6.0	16.1	.6	1.8	10.5	30.0
	Pulp.....	.02	.02	.40	.4	.2	.6	4.0	10.7	.5	1.2	8.8	20.0
Celery:													
Sprayed.....	Leaves.....									4.7-258.1	33.6-2	150.8	
	Stalks.....									.9-16.6	11.5-	207.5	
	Leaves ¹									2.1-85.5	15.0-	712.5	
	Stalks ¹									.7-8.2	8.7-	102.5	
Unsprayed.....	Whole.....									2.3		24.2	
Cucumbers:													
Sprayed.....	Whole.....									1.2	1.4	25.5	28.6
	Pulp.....									.3	.3	6.8	7.3
	Skin.....									2.5	2.8	38.5	44.4
Unsprayed.....	Whole.....									.6		11.3	
	Pulp.....									.3		7.1	
	Skin.....									.5		7.7	
Cranberries:													
Sprayed.....	Whole.....	0.10	3.90	0.80	30.7	0.6	19.1	4.9	150.4	1.3	33.3	10.6	208.5
	Whole ¹	.09	1.50	.70	11.8	.6	12.4	4.9	97.7	1.0	16.2	7.8	130.6
Unsprayed.....	Whole.....	.01	.10	.08	.7	.4	.7	2.9	5.6	.6	1.0	4.8	7.4
Grapes:													
Sprayed.....	Whole.....	.05	7.10	.26	35.5	.5	17.6	2.5	88.0	.6	6.4	2.9	33.8
	Whole ¹	.02	4.40	.10	24.0	.3	12.0	1.5	65.6	.3	4.2	1.4	22.2
Unsprayed.....	Whole.....	.00	.07	.00	.4	.5	1.1	2.6	6.8	.4	.9	2.1	4.7
Pears:													
Sprayed.....	Whole.....	.10	.32	.50	2.1	.3	1.0	1.6	6.7	1.5	3.0	10.0	14.5
	Pulp.....	.02	.10	.10	.8	.2	.2	1.0	1.7	.7	1.0	4.9	5.1
	Skin.....	.30	1.00	1.20	4.3	.8	3.2	3.1	13.7	4.5	16.2	19.3	54.5
	Calyx.....	1.20	6.40	4.80	27.7	4.2	21.3	16.7	92.2	12.1	21.9	52.4	68.9
	Skin ²	.30	.90	1.20	4.0	.8	3.0	3.1	13.4	2.1	12.4	9.0	41.8
	Calyx ²	1.20	6.40	4.80	27.7	4.2	21.3	16.7	92.2	7.8	8.2	25.8	33.8
Unsprayed.....	Whole.....	.05	.10	.30	.6	.2	.3	1.0	1.5	.3	.9	1.7	4.5
Apples:													
Sprayed.....	Whole.....	.03	5.50	.20	40.0	.3	17.0	2.2	130.0	.4	5.2	2.4	24.2
	Pulp.....	.02	.40	.10	2.5	.2	1.8	1.3	15.0	.3	.8	1.8	4.2
	Skin.....	.10	25.70	.50	130.0	.7	80.0	3.3	480.0	.6	28.5	2.8	111.3
	Calyx.....	.70	127.00	3.50	700.0	2.2	328.0	11.6	2,000.0	2.5	29.5	12.4	149.0
	Stem ends.....	.40	328.00	2.70	2,000.0	2.8	550.0	17.7	4,400.0	2.7	29.4	15.3	136.1
	Skin ²	.10	22.70	.50	92.3	.5	63.0	2.4	250.1	.6	28.5	2.8	111.3
	Calyx ²	.70	83.00	3.50	470.0	2.2	297.0	11.6	1,700.0	2.5	14.7	12.4	74.2
	Stem ends ²	.40	76.00	2.70	600.0	2.8	252.0	17.7	1,500.0	2.7	21.2	15.3	98.1
Unsprayed.....	Whole.....	.04	.44	.2	2.2	.2	1.5	1.3	9.3	.3	.7	2.3	4.3

TABLE 15.—*Arsenic, lead, and copper remaining on fruits and vegetables sprayed with poisonous sprays (summary)*—Continued.

Product.	Determination made on.	Arsenic in each fruit.		Lead in each fruit.		Copper in each fruit.	
		Mg.	Grains.	Mg.	Grains.	Mg.	Grains.
Peaches: Sprayed..	Whole...	0.002-0.115	0.000031-0.00180	0.024-0.297	0.00037-0.00460	.....	.....
	Pulp....	.000-.014	.000000-.00022	.007-.062	.00011-.00095	.....	.....
	Skin....	.001-.101	.000015-.00160	.013-.284	.00020-.00440	.....	.....
Unsprayed.	Whole...	.000-.026	.000000-.00040	.000-.057	.00000-.00058	.....	.....
	Pulp....	.000-.009	.000000-.00014	.000-.032	.00000-.00049	.....	.....
	Skin....	.000-.017	.000000-.00026	.000-.033	.00000-.00051	.....	.....
Pears: Sprayed..	Whole...	.013-.049	.000200-.00075	.039-.151	.000300-.00230	0.227-0.411	0.003500-0.00630
	Pulp....	.003-.010	.000046-.00015	.015-.029	.000230-.00045	.095-.120	.001500-.00180
	Skin....	.005-.023	.000077-.00035	.012-.073	.000180-.00110	.102-.251	.001600-.00400
	Calyx...	.002-.016	.000031-.00025	.005-.053	.000077-.00082	.030-.030	.000460-.00046
	Skin ² ...	.005-.014	.000077-.00022	.012-.054	.000180-.00083	.049-.200	.000750-.00310
	Calyx ² ...	.002-.016	.000031-.00025	.005-.053	.000077-.00082	.011-.020	.000170-.00031
Unsprayed.	Whole...	.006-.013	.000092-.00020	.022-.037	.000340-.00057	.033-.113	.000510-.00170
Apples: Sprayed..	Whole...	.004-.900	.000062-.01400	.036-2.800	.000550-.04300	.054-.380	.000830-.00590
	Pulp....	.002-.042	.000031-.00035	.015-.230	.000230-.00350	.035-.072	.000540-.00110
	Skin....	.002-.442	.000031-.00680	.010-1.600	.000150-.02500	.010-.273	.000150-.00420
	Calyx...	.001-.154	.000015-.00240	.003-.400	.000046-.00020	.003-.032	.000046-.00049
	Stem ends...	.001-.310	.000015-.00480	.003-.768	.000046-.01200	.003-.035	.000046-.00054
	Skin ² ...	.002-.345	.000031-.00530	.007-.958	.000110-.01500	.010-.273	.000150-.00420
	Calyx ² ...	.001-.127	.000015-.00200	.003-.332	.000046-.00510	.003-.016	.000046-.00025
	Stem ends ² ...	.001-.170	.000015-.00260	.003-.524	.000046-.00810	.003-.025	.000046-.00039
Unsprayed.	Whole...	.005-.051	.000077-.00079	.019-.178	.000290-.00270	.024-.093	.000370-.00140

¹ Washed.

² Wiped.

TABLE 16.—*Precipitation reports for sections where samples analyzed were harvested.*

BERLIN, MD., SECTION.

Date.	Precipitation.	Date.	Precipitation.	Date.	Precipitation.	Date.	Precipitation.
1915.	Inches.	1915.	Inches.	1915.	Inches.	1915.	Inches.
May 3....	Trace	June 1....	0.02	July 2....	0.58	Aug. 6....	.35
4....	0.08	2....	1.75	4....	.72	8....	.20
5....	.33	3....	1.20	5....	.80	9....	.25
12....	.63	5....	.01	8....	.07	10....	.20
13....	Trace.	6....	.08	11....	.57	12....	.28
15....	Trace.	12....	.07	13....	.58	14....	.04
16....	.44	13....	.13	17....	.48	21....	.01
17....	Trace.	14....	.05	20....	2.20	22....	.01
20....	.02	16....	.02	21....	.10	27....	Trace.
21....	.20	17....	.70			28....	.53
24....	.67	18....	Trace.			29....	.01
26....	.22	19....	.58			30....	.11
29....	.47	22....	.01				
30....	.32	27....	.22	Aug. 1....	Trace.		3.94
	3.38	30....	Trace.	2....	0.15		15.12
	13.26		4.84	3....	.60		
			13.84	4....	1.20		
				5....	Trace.		

¹ Normal.

TABLE 16.—*Precipitation reports for sections where samples analyzed were harvested—Continued.*

SPRINGFIELD, W. VA., SECTION.

Date.	Precipitation.	Date.	Precipitation.	Date.	Precipitation.	Date.	Precipitation.
	<i>Inches.</i>		<i>Inches.</i>		<i>Inches.</i>		<i>Inches.</i>
1915.		1915.		1916.		1916.	
May 3.....	0.21	June 1.....	Trace.	May 2.....	0.06	June 3.....	0.38
7.....	.15	2.....	1.46	3.....	.13	7.....	.30
12.....	.75	3.....	.05	4.....	.07	8.....	.31
16.....	1.05	7.....	.21	7.....	.38	9.....	.20
17.....	.20	11.....	Trace.	8.....	Trace.	10.....	.27
20.....	.21	13.....	.37	13.....	Trace.	15.....	.32
21.....	.03	14.....	.34	16.....	1.02	16.....	1.36
22.....	.57	16.....	.06	23.....	.42	19.....	.12
24.....	Trace.	22.....	.06	26.....	.13	21.....	.31
29.....	.42	26.....	.06	29.....	.30	25.....	.30
30.....	.67	30.....	.35	30.....	.50		
31.....	.05						
			2.96		3.01		3.87
	4.31		13.86		13.69		13.86
	13.69						
July 4.....	.35	Aug. 1.....	.10	July 2.....	.31	Aug. 3.....	.32
5.....	.13	2.....	1.05	10.....	.23	6.....	1.05
8.....	.17	3.....	1.10	12.....	.05	7.....	Trace.
11.....	.79	8.....	.30	13.....	.15	8.....	.10
12.....	.14	9.....	.18	14.....	.20	11.....	.11
15.....	.07	11.....	.15	16.....	.32	13.....	.34
16.....	.05	12.....	.13	17.....	.21	15.....	.14
19.....	Trace.	17.....	.40	18.....	.23	21.....	Trace.
20.....	.15	21.....	.42	21.....	.40	22.....	Trace.
21.....	.08	27.....	Trace.	25.....	.60	28.....	.60
22.....	Trace.	28.....	1.75				
25.....	.75		5.58		2.70		2.66
29.....	.64		13.88		13.57		13.88
	3.32						
	13.57						

FORT VALLEY, GA., SECTION.

1917.		1917.		1917.		1917.	
Apr. 2.....	0.62	May 12.....	Trace.	June 25.....	Trace.	July 14.....	Trace.
4.....	Trace.	23.....	.82	26.....	Trace.	16.....	.18
5.....	2.23	25.....	Trace.	27.....	Trace.	17.....	Trace.
8.....	.33	28.....	.63	29.....	.20	18.....	.53
13.....	Trace.			30.....	.10	19.....	.23
14.....	.23		2.91			20.....	1.03
22.....	Trace.		13.11		1.34	21.....	.10
26.....	Trace.				14.21	22.....	Trace.
		June 4.....	Trace.			23.....	Trace.
	3.41	10.....	Trace.	July 4.....	0.96	24.....	1.56
	14.28	14.....	0.10	5.....	.10	25.....	Trace.
May 4.....	0.30	15.....	.50	6.....	Trace.	26.....	.10
5.....	.61	22.....	Trace.	7.....	Trace.	27.....	Trace.
7.....	.45	23.....	0.44	8.....	Trace.		
8.....	0.10	24.....	Trace.	12.....	Trace.		4.79
11.....	Trace.						15.87

WENATCHEE, WASH., SECTION.

1916.		1916.		1916.		1916.	
May 5.....	0.09	May 31.....	0.04	June 24.....	0.06	July 2.....	0.99
6.....	.02			25.....	Trace.	8.....	Trace.
7.....	Trace.		.32	26.....	.17	15.....	Trace.
8.....	.10		1.86	27.....	.22	16.....	.52
9.....	Trace.			28.....	.06	27.....	Trace.
16.....	.01	June 3.....	Trace.	29.....	Trace.		
20.....	Trace.	18.....	Trace.	30.....	.01		1.51
24.....	Trace.	20.....	.17				1.38
29.....	.01	22.....	Trace.		1.04		
30.....	.05	23.....	.32		1.96		

¹ Normal.

TABLE 16.—*Precipitation reports for sections where samples analyzed were harvested—Continued.*

HART, MICH., SECTION.

Date.	Precipitation.	Date.	Precipitation.	Date.	Precipitation.	Date.	Precipitation.
1916.	Inches.	1916.	Inches.	1916.	Inches.	1916.	Inches.
May 1.....	0.75	June 8.....	0.72	July 31.....	Trace.	Sept. 7.....	0.65
3.....	Trace.	9.....	.28			12.....	.05
6.....	.15	14.....	.95			13.....	.14
8.....	.27	17.....	.45			14.....	Trace.
10.....	1.27	18.....	.04			15.....	.04
14.....	.30	23.....	.25	Aug. 3.....	.85	16.....	.18
15.....	.18	26.....	Trace.	4.....	.13	17.....	.14
17.....	.06	30.....	.97	5.....	.53	21.....	.17
22.....	.28			6.....	.10	22.....	.07
25.....	.05		4.94	10.....	.16	26.....	.16
27.....	.07		¹ 2.39	13.....	.10	27.....	.40
29.....	.45			26.....	.38	28.....	.14
		July 8.....	Trace.	30.....	.25		
	3.83	13.....	.15				3.11
	¹ 3.76	16.....	2.27		2.50		¹ 3.00
		20.....	.53		¹ 2.42		
June 2.....	.70	22.....	.04	Sept. 5.....	.97		
7.....	.58	25.....	.27				

CAMDEN, N. J., SECTION.

1915.		1915.		1915.		1915.	
July 1.....	0.19	July 21.....	0.20	Aug. 7.....	Trace.	Sept. 7.....	Trace.
2.....	.53	23.....	Trace.	8.....	1.05	12.....	0.08
3.....	Trace.	26.....	Trace.	9.....	.20	17.....	.29
4.....	.08	27.....	.28	12.....	.53	18.....	Trace.
5.....	Trace.	29.....	1.00	13.....	.01	19.....	.09
7.....	Trace.	30.....	.01	15.....	.05	21.....	.40
8.....	.67			17.....	Trace.	26.....	Trace.
11.....	Trace.		4.62	21.....	Trace.		
12.....	.64		¹ 4.30	25.....	.07		.86
14.....	.35			28.....	.03		¹ 3.74
15.....	Trace.	Aug. 1.....	.13	29.....	1.05		
16.....	.27	2.....	.02	30.....	.74		
17.....	.15	3.....	.32				
18.....	Trace.	4.....	2.10		6.61		
19.....	.25	5.....	Trace.		¹ 4.59		
20.....	Trace.	6.....	.31				

ARLINGTON, VA., SECTION.

1916.		1916.		1916.		1916.	
July 2.....	0.01	Aug. 4.....	0.13	Sept. 6.....	0.06	Oct. 6.....	Trace.
3.....	Trace.	6.....	1.46	7.....	Trace.	9.....	0.03
9.....	.34	8.....	.17	8.....	.31	10.....	.01
10.....	.73	9.....	Trace.	9.....	Trace.	13.....	.09
15.....	.04	13.....	.19	14.....	Trace.	15.....	.02
16.....	Trace.	16.....	.30	15.....	1.17	16.....	.04
17.....	.03	23.....	.05	18.....	.18	17.....	Trace.
19.....	.09	27.....	.45	22.....	.46	18.....	.05
20.....	Trace.	28.....	.08	23.....	Trace.	19.....	1.24
22.....	1.67	30.....	Trace.	29.....	.38	20.....	.02
24.....	.15					31.....	.26
25.....	1.85		2.83		2.57		
26.....	.02		¹ 4.40		¹ 3.59		1.76
28.....	.04						¹ 3.09
	4.97	Sept. 2.....	.01	Oct. 5.....	Trace.		
	¹ 4.65						

SALEM, N. J., SECTION.

1916.		1916.		1916.		1916.	
July 10.....	1.60	Aug. 1.....	0.05	Sept. 2.....	Trace.	Sept. 19.....	0.20
13.....	.34	8.....	.30	6.....	0.20	29.....	.52
20.....	.48	11.....	.18	7.....	.22		
21.....	.02	13.....	Trace.	8.....	.37		1.83
22.....	1.80	14.....	.08	15.....	.32		¹ 3.81
23.....	.05	27.....	.42				
25.....	.90	28.....	.20				
26.....	.05						
	5.24		1.23				
	¹ 4.43		¹ 4.74				

¹ Normal.

TABLE 16.—*Precipitation reports for sections where samples analyzed were harvested—*
Continued.

NORTH LIBERTY, IND., SECTION.

Date.	Precipitation.	Date.	Precipitation.	Date.	Precipitation.	Date.	Precipitation.
1915.	Inches.	1915.	Inches.	1915.	Inches.	1917.	Inches.
Aug. 2.....	0.70	Sept. 7.....	0.01	Oct. 17.....	0.03	Oct. 4.....	Trace.
3.....	.23	10.....	.22	18.....	.10	5.....	0.13
4.....	.05	11.....	.02		1.86	10.....	.15
5.....	.01	12.....	Trace.		12.42	11.....	.11
6.....	.02	16.....	.74			12.....	.06
11.....	.40	17.....	.35	1917.		13.....	Trace.
12.....	1.49	18.....	.32	Sept. 2.....	.04	14.....	.03
13.....	.04	20.....	.54	5.....	Trace.	17.....	1.23
16.....	.08	26.....	1.12	6.....	.69	18.....	1.20
17.....	Trace.	27.....	.09	7.....	.55	19.....	.29
20.....	.09		4.21	8.....	Trace.	21.....	.07
21.....	1.31		13.03	14.....	.05	23.....	.38
24.....	.12	Oct. 1.....	.10	20.....	.10	26.....	.63
	4.54	4.....	.56	27.....	.04	27.....	.14
	13.26	8.....	.13		1.47	29.....	.68
Sept. 4.....	Trace.	9.....	.40		13.03	30.....	.06
5.....	.25	13.....	.54	Oct. 3.....	.15	31.....	Trace.
6.....	.55						5.31
							12.42

PLYMOUTH, IND., SECTION.

1916.		1916.		1916.		1916.	
July 2.....	Trace.	Aug. 7.....	0.15	Sept. 1.....	Trace.	Sept. 26.....	0.02
12.....	0.05	10.....	.04	4.....	0.19	27.....	1.73
13.....	.51	11.....	1.55	5.....	2.01	28.....	.18
14.....	.02	15.....	Trace.	6.....	1.09		
19.....	.41	16.....	.02	13.....	Trace.		5.22
	.99	18.....	.27	17.....	Trace.		13.27
	13.38	27.....	.32				
			2.73				
Aug. 4.....	.38		13.49				

EAST WAREHAM, MASS., SECTION.

Date.	Precipitation.	Date.	Precipitation.	Date.	Precipitation.	Date.	Precipitation.
1916.		1916.		1916.		1917.	
June 4.....	0.40	Aug. 8.....	0.47	Oct. 21.....	0.39	Aug. 3.....	0.06
8.....	.18	9.....	.24	26.....	.27	5.....	.03
9.....	.96	10.....	.60		2.85	9.....	.07
10.....	.27	12.....	.17		4.18	10.....	.43
11.....	.19	13.....	.29			16.....	.38
12.....	.67	24.....	Trace.	1917.		17.....	.95
13.....	.18	26.....	Trace.	June 2.....	.08	21.....	.10
17.....	.68	27.....	.20	6.....	.28	23.....	.07
18.....	.27	28.....	.22	11.....	2.00	24.....	.03
19.....	Trace.		2.19	12.....	1.42	25.....	.44
22.....	.35		13.26	13.....	.05	29.....	.04
26.....	.65	Sept. 2.....	.12	16.....	.62	30.....	.70
29.....	.37	6.....	.71	17.....	1.69		3.30
	5.17	7.....	Trace.	24.....	.23		13.26
	12.68	9.....	.12	27.....	.15	Sept. 8.....	.18
July 3.....	.78	15.....	.50	29.....	.13	18.....	1.87
4.....	.08	16.....	.07		6.65	20.....	.24
5.....	.12	19.....	.10		12.68	24.....	.02
10.....	1.33	23.....	.13	July 1.....	Trace.	28.....	.44
14.....	.52	25.....	.05	4.....	.52	30.....	.10
17.....	.15	30.....	.67	12.....	.22		2.85
18.....	.10		2.47	13.....	Trace.		13.56
21.....	.78		13.56	15.....	.08		
23.....	4.13	Oct. 9.....	.09	19.....	.18	Oct.....	5.02
24.....	.15	13.....	.27	27.....	1.23		14.18
26.....	.49	17.....	.11		2.23		
27.....	.16	18.....	Trace.		13.10		
31.....	.21	20.....	1.72				
	9.00						
	13.10						

¹ Normal.² Total; daily data not reported.

TABLE 16.—*Precipitation reports for sections where samples analyzed were harvested—Continued.*

NORTH EAST, PA., SECTION.

Date.	Precipitation.	Date.	Precipitation.	Date.	Precipitation.	Date.	Precipitation.
	Inches.		Inches.		Inches.		Inches.
1915.		1915.		1915.		1916.	
July 1.....	Trace.	Aug. 22.....	0.33	Oct. 18.....	0.15	Sept. 1.....	0.16
2.....	0.03	24.....	.81	19.....	.02	4.....	.11
3.....	.65	28.....	.21	21.....	Trace.	5.....	.16
4.....	.12	29.....	.03	28.....	Trace.	7.....	1.61
5.....	.19	30.....	Trace.	29.....	Trace.	8.....	.81
7.....	.19					14.....	.32
8.....	1.24		9.28		2.21	15.....	.01
11.....	.81		13.26		13.80	16.....	.01
12.....	.86					17.....	.06
15.....	.13	Sept. 4.....	Trace.	1916.		18.....	.01
16.....	.18	5.....	.05	July 2.....	.32	21.....	.13
17.....	.04	6.....	.36	3.....	Trace.	22.....	.18
19.....	.08	8.....	.07	4.....	Trace.	23.....	.16
21.....	.09	10.....	.01	13.....	.02	26.....	Trace.
25.....	.19	12.....	.31	16.....	.01	28.....	.59
26.....	.02	13.....	.50	18.....	Trace.	29.....	.15
28.....	.32	15.....	1.49	19.....	Trace.		
30.....	Trace.	17.....	.15	20.....	Trace.		4.47
31.....	Trace.	18.....	.55	25.....	Trace.		13.49
		19.....	Trace.	31.....	.04		
	5.14	21.....	.11			Oct. 9.....	.17
	13.21	24.....	.01		.39	13.....	1.00
		25.....	.58		13.21	16.....	.23
Aug. 2.....	Trace.			Aug. 3.....	Trace.	17.....	.05
3.....	5.40		4.19	4.....	.03	19.....	.67
4.....	.38		13.49	5.....	.54	20.....	.26
5.....	.19			8.....	.71	21.....	.07
7.....	.02	Oct. 1.....	.38	11.....	Trace.	22.....	.08
8.....	.01	2.....	.04	13.....	.49	25.....	.08
9.....	.04	4.....	Trace.	16.....	Trace.	26.....	.06
11.....	Trace.	5.....	.10	22.....	.17	27.....	.01
12.....	.66	6.....	Trace.	23.....	Trace.	31.....	.20
13.....	.29	7.....	Trace.	26.....	Trace.		2.88
14.....	.07	8.....	.20	27.....	.75		13.80
15.....	.24	9.....	.28				
17.....	.04	13.....	Trace.		2.69		
20.....	.02	14.....	1.94		13.26		
21.....	.51	15.....	Trace.				

SANDUSKY, OHIO, SECTION.

1916.		1916.		1916.		1917.	
June 2.....	0.43	Aug. 3.....	Trace.	Oct. 8.....	0.07	June 19....	0.11
3.....	.12	4.....	0.03	9.....	.11	21.....	Trace.
4.....	.29	5.....	.02	12.....	Trace.	22.....	.12
6.....	.28	8.....	.48	13.....	.28	23.....	.22
7.....	.72	11.....	.81	16.....	.07	26.....	Trace.
8.....	.01	16.....	.15	18.....	.11	28.....	.18
9.....	.34	19.....	Trace.	19.....	.42	29.....	.01
10.....	.28	22.....	.67	20.....	.15		
16.....	.81	27.....	.12	21.....	Trace.		4.21
17.....	Trace.		2.28	24.....	Trace.		13.82
18.....	.25		13.37	25.....	.01		
19.....	.01			27.....	Trace.	July 7.....	.08
20.....	Trace.	Sept. 2.....	Trace.	31.....	.02	9.....	.01
21.....	.57	4.....	Trace.			10.....	Trace.
24.....	.17	5.....	Trace.		1.24	11.....	.03
26.....	Trace.	7.....	.63		12.43	12.....	.08
30.....	.08	8.....	.12			13.....	.09
		14.....	.05	1917.		14.....	Trace.
	4.36	17.....	Trace.	June 2.....	.07	16.....	.12
	13.82	21.....	.01	5.....	2.33	17.....	Trace.
July 2.....	.03	22.....	.03	6.....	.66	21.....	.05
12.....	Trace.	23.....	Trace.	9.....	.08	26.....	Trace.
13.....	.11	26.....	.20	10.....	Trace.		.46
20.....	.12	27.....	.09	12.....	Trace.		13.79
		28.....	.90	13.....	.14		
				14.....	Trace.		
	26		2.03	15.....	.28	Aug. 2.....	.01
	13.79		12.68	16.....	.01	5.....	.20
				17.....	Trace.	7.....	.12

1 Normal.

TABLE 16.—*Precipitation reports for sections where samples analyzed were harvested.*—Continued.

SANDUSKY, OHIO, SECTION—Continued.

Date.	Precipitation.	Date.	Precipitation.	Date.	Precipitation.	Date.	Precipitation.
1917.	Inches.	1917.	Inches.	1917.	Inches.	1917.	Inches.
Aug. 8....	0.07	Sept. 2....	0.02	Oct. 2....	0.03	Oct. 27....	.24
9....	Trace.	5....	.03	3....	.67	28....	0.44
13....	.54	6....	.73	4....	.08	29....	1.19
16....	.38	7....	.23	5....	.05	30....	.06
20....	Trace.	20....	Trace.	7....	Trace.	31....	.03
21....	.01	27....	1.31	8....	Trace.		
22....	.03	29....	.02	11....	.02		6.22
23....	1.79	30....	Trace.	12....	.72		12.43
25....	Trace.			14....	Trace.		
27....	Trace.		2.34	17....	Trace.		
28....	.50		12.68	18....	.63		
29....	.30			19....	.85		
30....	.04			22....	.04		
	3.99			23....	.54		
	13.37			24....	Trace.		
				26....	.18		

MOORESTOWN AND BROWN MILLS, N. J., SECTIONS.

1915.		1915.		1915.		1916.	
Apr. 3....	0.69	July 1....	0.03	Oct. 15....	0.14	July 10....	0.90
4....	.17	2....	.37	16....	.20	14....	1.33
6....	.03	5....	.40	27....	.40	15....	.05
11....	.73	8....	1.04			17....	.43
21....	Trace.	12....	.73		2.37	20....	.05
23....	Trace.	14....	.53		13.64	21....	.52
27....	.07	16....	.97			22....	.51
28....	.10	17....	.33	1916.		23....	.05
29....	.55	19....	.35	May 4....	.03	25....	1.28
30....	.50	21....	.10	5....	.39	26....	.30
	2.84	27....	.33	7....	.21		
	13.19	29....	.64	9....	.43		5.42
		31....	.06	14....	Trace.		14.58
				16....	.35		
May 4....	.39		5.88	17....	.19	Aug. 8....	.67
5....	.69		14.58	18....	.03	12....	.38
9....	.64	Aug. 1....	.19	23....	.59	16....	Trace.
12....	.36	3....	.27	24....	.02	24....	.09
13....	.42	4....	2.11	25....	1.05	28....	.43
16....	.07	6....	.21	29....	.03		
17....	.26	8....	.20				1.57
21....	.70	9....	.37		3.32		14.74
22....	1.50	12....	.47		14.03		
23....	.15	15....	.04	June 4....	.10	Sept. 6....	Trace.
24....	.17	25....	.04	5....	.17	7....	.05
25....	.02	28....	Trace.	7....	1.40	8....	.48
26....	.06	29....	1.05	8....	.15	15....	.36
30....	.34	30....	.80	13....	.42	19....	.13
	5.77			16....	.14	29....	.68
	14.03		5.75	17....	.06	30....	.11
			14.74	19....	.23		
June 2....	.63			20....	.40		1.81
3....	.14	Sept. 12....	.06	21....	.26		13.76
4....	.04	18....	.12	25....	.45	Oct. 13....	.20
12....	.14	19....	.13			19....	.85
13....	1.55	21....	.38		3.78		
15....	.44	26....	Trace.		13.80		1.05
16....	.43						13.64
17....	.03		.69				
22....	.45		13.76				
23....	.17	Oct. 1....	.44				
26....	.09	2....	.26				
28....	Trace.	5....	.28				
	4.11	7....	Trace.				
	13.80	8....	.65				
		14....	Trace.				

1 Normal.

TABLE 16.—*Precipitation reports for sections where samples analyzed were harvested—Continued.*

ROSEWELL, N. MEX., SECTION.

Date.	Precipitation.	Date.	Precipitation.	Date.	Precipitation.	Date.	Precipitation.
	<i>Inches.</i>		<i>Inches.</i>		<i>Inches.</i>		<i>Inches.</i>
1915.		1915.		1915.		1916.	
Apr. 1....	Trace.	July 3....	Trace.	Sept. 25....	0.39	July 20....	Trace.
6.....	0.01	5.....	Trace.	29.....	.71	27.....	0.01
7.....	.06	8.....	Trace.			28.....	.02
8.....	Trace.	11.....	0.04		2.29	29.....	.08
9.....	Trace.	19.....	.12		12.29		
10.....	.17	20.....	.13				1.04
13.....	.27	21.....	.01	Oct. 5....	.09		13.46
14.....	.01	23.....	.01	11.....	.01		
15.....	1.44	24.....	.02	14.....	Trace.	Aug. 7....	1.00
16.....	3.43	25.....	.01	15.....	.02	8.....	4.57
17.....	.23	26.....	Trace.			16.....	.27
18.....	.01	27.....	.10		.12	17.....	.32
19.....	.02	28.....	.01		11.52	18.....	.06
21.....	Trace.					19.....	1.07
22.....	Trace.		.45	1916.		20.....	.30
23.....	Trace.		13.46	Apr. 12....	.07	21.....	.01
24.....	.09	Aug. 7....	Trace.	13.....	.36	22.....	.52
25.....	.02	8.....	.28	14.....	.24	23.....	1.39
29.....	.23	9.....	.03	25.....	.02	27.....	.05
		11.....	.23	26.....	.39	30.....	Trace.
	6.04	12.....	.01	30.....	.03		
	1.49	14.....	.48				9.56
May 5....	.04	18.....	.01		1.11		11.46
23.....	.93	19.....	.08		1.49		
26.....	Trace.	20.....	.01	May 1....	.17	Sept. 2....	.01
27.....	.01	21.....	Trace.		11.17	4.....	Trace.
30.....	.02	22.....	Trace.			10.....	Trace.
31.....	.18	23.....	.52	June 8....	Trace.	12.....	.30
		27.....	.09	12.....	.44	19.....	.06
	1.18	29.....	.03	19.....	Trace.	30.....	Trace.
	11.17			24.....	Trace.		
			1.77				.37
June 9....	.06		11.46		.44		12.29
10.....	.01	Sept. 2....	.09		12.08	Oct. 10....	.14
15.....	Trace.	4.....	.01	July 4....	Trace.	11.....	.37
23.....	.06	14.....	.01	6.....	.68	12.....	.76
25.....	.01	16.....	.08	7.....	.05	13.....	.76
26.....	Trace.	18.....	.01	11.....	Trace.	14.....	.22
27.....	Trace.	21.....	.03	12.....	.04	16.....	.01
		22.....	.22	17.....	Trace.	27.....	.05
	.14	23.....	.01	18.....	.01		
	12.08	24.....	.73	19.....	.15		2.31
							11.52

BENTON HARBOR, MICH., SECTION.

1915.		1915.		1915.		1915.	
May 2....	Trace.	June 7....	0.09	July 15....	0.30	Aug. 16....	Trace.
3.....	0.60	8.....	Trace.	18.....	.80	21.....	0.61
4.....	Trace.	9.....	Trace.	20.....	Trace.	24.....	.21
6.....	Trace.	10.....	.24	24.....	.23		
7.....	.15	11.....	.12	25.....	.10		5.21
8.....	.45	12.....	Trace.	27.....	.17		12.23
13.....	.50	13.....	.47	28.....	.15		
14.....	Trace.	14.....	.08	29.....	.20	Sept. 5....	.20
15.....	.22	15.....	.07	30.....	.30	6.....	1.12
16.....	.32	16.....	Trace.	31.....	.18	7.....	.06
17.....	Trace.	17.....	.04			10.....	.19
20.....	Trace.	18.....	.08		6.53	12.....	.70
21.....	.30	20.....	.25		12.52	15.....	Trace.
24.....	.50	21.....	.02			16.....	.40
25.....	.10			Aug. 2....	1.21	17.....	.40
26.....	Trace.		1.46	3.....	1.65	18.....	.60
28.....	.90		12.95	4.....	.25	20.....	1.15
29.....	.60	July 4....	.63	5.....	.20	21.....	Trace.
30.....	.20	7.....	1.20	7.....	.55	26.....	1.23
		8.....	.90	8.....	Trace	27.....	Trace.
	4.84	11.....	.20	11.....	.20		6.05
	13.89	14.....	1.17	12.....	.17		13.06
				13.....	.16		

† Normal.

TABLE 16.—*Precipitation reports for sections where samples analyzed were harvested—Continued.*

BENTON HARBOR, MICH., SECTION—Continued.

Date.	Precipitation.	Date.	Precipitation.	Date.	Precipitation.	Date.	Precipitation.
1915.	<i>Inches.</i>	1916.	<i>Inches.</i>	1916.	<i>Inches.</i>	1916.	<i>Inches.</i>
Oct. 4....	0.30	May 29....	1.06	July 16....	0.12	Sept. 13....	0.30
7....	Trace.	30....	.30	28....	.39	22....	.40
8....	.70					26....	.04
9....	Trace.		7.01		.51	27....	.68
13....	.25		1 3.89		1 2.52	28....	.15
17....	.30	June 2....	.23	Aug. 3....	.80	29....	.38
18....	.22		.03	5....	.53		
19....	.20	6....	.10	8....	Trace.		3.57
	1.97	7....	1.05	10....	.69		1 3.06
	1 2.76	8....	.49	11....	.50	Oct. 9....	.15
1916.		9....	.04	24....	Trace.	13....	.10
May 6....	.10	14....	.61	26....	.20	15....	Trace.
8....	.18	16....	.06	28....	.20	20....	1.25
10....	.50	18....	.05			21....	.45
13....	.40	20....	.02		2.92	25....	.12
14....	.57	21....	.37		1 2.28	26....	Trace.
15....	.70	23....	.12	Sept. 4....	.20	29....	Trace.
19....	.70	24....	.27		1.20		
21....	.30	26....	.52	7....	.20		2.07
22....	.70	30....	.05	12....	.02		1 2.76
26....	.70		4.01				
28....	.80		1 2.95				

GRAND JUNCTION, COLO., SECTION.

1915.		1915.		1916.		1916.	
May.....	² 1.23	Sept. 2....	Trace.	July 16....	Trace.	Oct. 1....	0.08
	² .92	3....	0.05	17....	Trace.	3....	.10
June 1....	.20	4....	.04	20....	Trace.	4....	.27
3....	.03	7....	Trace.	23....	Trace.	5....	.06
4....	.08	8....	.02	24....	Trace.	6....	.05
5....	.40	13....	Trace.	25....	.33	7....	.51
6....	.19	24....	.03	26....	.07	9....	Trace.
9....	Trace.	25....	.81	27....	.11	10....	.51
18....	.02		.95	28....	.01	11....	.03
28....	Trace.		1.95	29....	.02	14....	.37
	.92	Oct. 14....	Trace.	30....	Trace.	15....	.06
	1.40	15....	.01		.76	18....	.08
July 5....	.02		.01		1.50		2.12
12....	Trace.		1.91	Aug. 3....	.73		1.91
26....	.01			4....	Trace.		
27....	Trace.	1916.		5....	.10	1917.	
28....	Trace.	May 2....	Trace.	6....	.13	May 1....	Trace.
29....	.13	13....	Trace.	8....	Trace.	2....	.02
	.16	18....	Trace.	9....	Trace.	4....	.01
	1.50	19....	.26	12....	.60	5....	.18
Aug. 5....	Trace.	20....	.78	13....	.25	7....	.01
6....	Trace.	21....	.01	15....	Trace.	8....	Trace.
7....	.25	22....	Trace.	16....	.26	9....	Trace.
11....	Trace.		1.05	20....	Trace.	12....	.12
14....	Trace.		1.92	29....	.08	15....	.04
15....	.05	June 5....	Trace.	30....	.01	20....	.07
16....	Trace.	18....	Trace.		2.16	21....	.11
22....	.01				1 1.04	22....	.24
23....	.09			Sept. 2....	Trace.	23....	.01
24....	.01			5....	.21	25....	.04
25....	.01			8....	.01	26....	.03
26....	.01	July 5....	Trace.	9....	.27	27....	.01
29....	Trace.	6....	Trace.	17....	Trace.	28....	.01
	.51	8....	.20	22....	.01	29....	.08
	1.04	9....	Trace.	23....	Trace.	30....	.15
		14....	.01		.50	31....	.32
		15....	.01		1.95		1.45
							1.92

¹ Normal.

POISONOUS METALS ON SPRAYED FRUITS AND VEGETABLES. 57

TABLE 16.—*Precipitation reports for sections where samples analyzed were harvested—Continued.*

GRAND JUNCTION, COLO., SECTION—Continued.

Date.	Precipitation.	Date.	Precipitation.	Date.	Precipitation.	Date.	Precipitation.
1917.	<i>Inches.</i>	1917.	<i>Inches.</i>	1917.	<i>Inches.</i>	1917.	<i>Inches.</i>
June 1.....	Trace.	July 28.....	Trace.	Aug. 26.....	0.01	Sept. 12.....	0.15
4.....	0.01	29.....	0.07	27.....	Trace.	22.....	.10
10.....	Trace.	30.....	.21	28.....	.03	23.....	.02
21.....	Trace.			31.....	Trace.	25.....	.02
			.28			30.....	Trace.
	.01		1.50		.38		1.00
	1.40				1.04		1.95
July 5.....	Trace.	Aug. 4.....	Trace.	Sept. 2.....	Trace.		
6.....	Trace.	9.....	Trace.	4.....	.01	Oct. 1.....	Trace.
10.....	Trace.	12.....	.02	5.....	Trace.	17.....	Trace.
20.....	Trace.	13.....	.22	6.....	.04	24.....	Trace.
24.....	Trace.	14.....	Trace.	8.....	.01		
25.....	Trace.	17.....	Trace.	9.....	.01		Trace.
26.....	Trace.	18.....	.01	10.....	.64		1.91

GREENWOOD, VA., SECTION.

1917.		1917.		1917.		1917.	
Apr. 5.....	2.33	June 1.....	0.43	July 16.....	0.16	Sept. 2.....	0.05
8.....	.30	2.....	.27	17.....	.14	6.....	.23
13.....	.44	5.....	.03	18.....	.01	7.....	.58
18.....	Trace.	9.....	1.40	21.....	.05	8.....	.36
21.....	.08	10.....	.22	22.....	.07	9.....	.04
24.....	.05	11.....	.03	24.....	.35	15.....	.19
25.....	.12	12.....	.01	25.....	.48	16.....	.05
27.....	.06	14.....	.38	26.....	.10	21.....	.01
28.....	.43	15.....	.01			27.....	.77
		20.....	.12		3.78		
	3.81	23.....	.64		14.89		2.28
	13.22	25.....	.18				14.18
		26.....	.02	Aug. 2.....	.46		
May 1.....	.03	27.....	.38	7.....	.01		
4.....	.78	28.....	1.37	8.....	1.08		
7.....	.38			9.....	2.21		
8.....	.13		5.49	14.....	.01		
11.....	Trace.		15.48	15.....	Trace.		
22.....	.02	July 2.....	.36	16.....	.13		
26.....	Trace.	3.....	.07	23.....	2.80		
27.....	.65	7.....	.28	24.....	.73		
28.....	.68	8.....	.81	30.....	.60		
		10.....	.75	31.....	.08		
	2.67	11.....	.13				
	14.62	14.....	.02		8.11		
		15.....	Trace.		15.00		

YAKIMA, WASH., SECTION.

1919.		1919.		1919.		1919.	
May 4.....	0.04	July 5.....	Trace.	Sept. 4.....	Trace.	Oct. 1.....	0.12
5.....	.18	6.....	Trace.	5.....	0.05	17.....	Trace.
11.....	Trace.	10.....	.03	6.....	.01	21.....	Trace.
15.....	.03	11.....	Trace.	8.....	.09	22.....	Trace.
16.....	Trace.	23.....	Trace.	10.....	Trace.	23.....	Trace.
25.....	.33	31.....	Trace.	11.....	.44	26.....	Trace.
				12.....	.01	31.....	Trace.
	.58		.03	27.....	.02		
	1.83		1.25	28.....	.01		.12
				30.....	.06		1.51
June 9.....	Trace.	Aug. 3.....	Trace.				
10.....	Trace.	30.....	Trace.		.69		
11.....	Trace.	31.....	.08		1.48		
13.....	.04						
	.04		.08				
	1.52		1.12				

¹ Normal.

SUMMARY.

The amounts of arsenic, lead, and copper remaining on mature fruits and vegetables which have been sprayed according to various schedules were determined in the Bureau of Chemistry. Table 15 gives the maximum and minimum results.

Because of overspraying or late spraying, comparatively large quantities of spray residues were found in some cases. This emphasizes the importance of spraying according to the schedules recommended by the Bureaus of Entomology and Plant Industry.

The extent of the reduction of spray residues on the mature fruit and vegetables by washing and wiping them was determined by a series of analyses before and after such treatment.

When peeled, sprayed fruits and vegetables contain essentially the same amounts of arsenic, lead, and copper as the unsprayed products, indicating that practically all of the spray residues can be removed by peeling.

From the results reported in this bulletin it is evident that when fruits and vegetables are sprayed in accordance with the schedules recommended by the Bureaus of Entomology and Plant Industry, but little of the material used remains on the fruit or vegetable at harvest time.

LITERATURE CITED.

- (1) ACADEMY OF MEDICINE (FRANCE).
Proc. Acad. Med., Feb. 18, 1908. Bull. acad. med., 3 ser., **59** (1908): 246.
- (2) ————
Proc. Acad. Med., Feb. 2, 1909. Bull. acad. med., 3 ser., **61** (1909): 194.
- (3) ————
Sur un projet de décret portant modification de l'ordonnance de 1846 relative à la vente des substances vénéneuses. Bull. acad. med., 3 ser., **70** (1913): 152.
- (4) ————
Proc. Acad. Med., Nov. 11, 1913. Bull. acad. med., 3 ser., **70** (1913): 368, 369.
- (5) ————
Proc. Acad. Med., Mar. 3, 1914. Bull. acad. med., 3 ser., **71** (1914): 324, 325, 326.
- (6) ALWOOD, W. B.
Treatment of diseases of the grape. Va. Agr. Exp. Sta. Bull. 15 (1892): 41.
- (7) AMPOLA, G., and TOMMASI, G.
I composti di arsenico in agricoltura. Ann. staz. chim. agrar. sper. Roma, 2 ser., **5** (1911): 241; J. Soc. Chem. Ind., **31** (1912): 891; Chem. Abst., **7** (1913): 1255; Exp. Sta. Rec., **30** (1914): 130.
- (8) ANDOUARD, A.
Le cuivre dans les vins provenant de vignes traitées par le sulfate de cuivre. Compt. rend., **104** (1887): 195; Bull. soc. nat. agr. (France), **47** (1887): 40; J. pharm. chim., 5 ser., **15** (1887): 290.

- (9) ANONYMOUS.
Spraying fruits for insect pests and fungous diseases. U. S. Dept. Agr.,
Farmers' Bull. 7 (1892): 17-20.
- (10) ———.
Fruit spraying. J. Roy. Hort. Soc., 18 (1895): 185.
- (11) BAKER, J. L.
A résumé of the report minutes of evidence and appendices of the Royal
Commission on Arsenical Poisoning. J. Soc. Chem. Ind., 23 (1904): 168.
- (12) BEACH, S. A.
Some celery diseases. N. Y. Agr. Exp. Sta. Bull. 51, n. ser. (1893): 146;
Exp. Sta. Rec., 4 (1892-93): 926.
- (13) BEDINI, R.
I sali arsenicali in frutticoltura. L'istria agricola, 3 yr. (1910): 538.
- (14) BERTIN-SANS, H., and Ros, V.
L'emploi de l'arsenic en agriculture ses dangers. Rev. hyg. pol. sanit.,
29 yr. (1907): 193.
- (15) ———.
À propos de l'utilisation des composés arsenicaux en agriculture. Rev.
hyg. pol. sanit., 30 yr. (1908): 281; Exp. Sta. Rec., 20 (1908-09): 459.
- (16) BOUFFARD, M.
La présence du cuivre métallique dans les vins provenant des vignes
traitées au sulfate de cuivre. Bull. ministère agr. 8 (1887): 832.
- (17) BRETEAU, P.
Sur la teneur en arsenic des vins provenant de vignes traitées par les com-
posés de l'arsenic. J. pharm. chim., 6 ser., 28 (1908): 154; Chem. Abst.,
2 (1908): 3257.
- (18) BRIOUX and GRIFFON.
Les traitements arsenicaux en arboriculture fruitière. Bull. soc. nat. agr.
(France), 70 (1910): 864.
- (19) CARLES, P.
À propos du cuivre dans les tomates. Répert. pharm., 3 ser., 28 (1917):
193; Rev. sci., 55 yr. (1917): 183; Chem. Abst., 12 (1918): 192; Exp. Sta.
Rec., 37 (1917): 263.
- (20) ——— and BARTHE, L.
Recherche de l'arsenic de plomb dans des vins, des lies et des pépins
provenant de vignes traitées à l'arséniate de plomb. Bull. soc. chim.,
4 ser., 11 (1912): 413; Chem. Abst., 6 (1912): 1805; Exp. Sta. Rec., 27
(1912): 243.
- (21) CAZENEUVE, P.
Sur les dangers de l'emploi des insecticides à base arsenicale en agriculture
au point de vue de l'hygiène publique. Bull. acad. med., 3 ser., 59
(1908): 133, 234.
- (22) ———.
Proc. Acad. Med., Nov. 18, 1913. Bull. acad. med., 3 ser., 70 (1913): 415.
- (23) CHUARD, E.
Observations concernant le mécanisme de l'introduction et de l'élimina-
tion du cuivre dans les vins provenant de vignes traitées par les com-
binaisons cuivriques. Compt. rend., 105 (1887): 1196.
- (24) ———.
Présence et l'élimination de l'arsenic des vins. Trav. chim. alim. hyg.
bur. sanit. fed., 1, (1910): 82.

- (25) COMBONI, E.
Chemische Untersuchungen über die Weine aus Trauben, die mit kupferhaltigen Schutzmitteln gegen die *Peronospora* behandelt worden waren. *Nuova Rassegna Vitic.*, 2: 209; *through Chem. Centr.*, 3 ser., 19 yr. (1888): 875.
- (26) COOK, A. J.
Two new uses of important insecticides. *Proc. 29 Meeting Am. Assoc. Adv. Sci.* (1880): 669.
- (27) ———
Experiments with insecticides. *Proc. 2 Ann. Meeting Soc. Prom. Agr. Sci.* (1881): 112.
- (28) CROLAS and RAULIN.
Traitement de la vigne par les sels de cuivre contre le mildew. *Compt. rend.*, 103 (1886): 1068; *J. pharm. chim.*, 5 ser., 15 (1887): 156.
- (29) CUGINI, G.
Ueber die Bekämpfung der *Peronospora Viticula* und den Einfluss der Mittel auf die Zusammensetzung des Mostes und Weines. *Nat. Bot. Kongr. Parma*, 1 (1887): 5; *through Chem. Centr.*, 3 ser., 19 yr. (1888): 532.
- (30) DAVIS, G. C.
Celery insects. *Mich. Agr. Exp. Sta. Bull.* 102 (1893): 44.
- (31) DUCLAUX, E.
Sur le dosage de très petites quantités de cuivre et la présence de ce métal dans les cacaoes et chocolats. *Bull. soc. chim.* 16 (1871): 33.
- (32) DUGUET ET AL.
Proc. Acad. Med., June 28, 1910. *Bull. acad. med.*, 3 ser., 63 (1910): 657.
- (33) ———
Proc. Acad. Med., Mar. 7, 1911. *Bull. acad. med.*, 3 ser., 65 (1911): 346.
- (34) ———
Proc. Acad. Med., July 11, 1911. *Bull. acad. med.*, 3 ser., 66 (1911): 59.
- (35) DUPRÉ, A.
On copper in food. *Analyst*, 2 (1878): 1.
- (36) FALLOT, B.
Le cuivre dans les vins. *Prog. agr. vit.*, June 16, 1889; *through U. S. Dept. Agr., Div. Bot. Bull.* 11 (1890): 96.
- (37) FETEL, P.
De la teneur en arsenic des raisins d'Algérie et en particulier des raisins provenant des vignes ayant subi des traitements aux sels arsenicaux. *Bull. agr. Algérie et Tunisie*, 16 (1910): 430; *Exp. Sta. Rec.*, 25 (1911): 40.
- (38) FLETCHER, J.
The results of an experiment to prove that apples are not poisoned by spraying with Paris green for codling moth. *Can. Exp. Farms Rpt. for 1891*, p. 189; *Exp. Sta. Rec.*, 4 (1892-93): 437.
- (39) FORBES, S. A.
Spraying apples for the plum curculio. *Ill. Agr. Exp. Sta. Bull.* 108 (1906): 279; *Exp. Sta. Rec.* 18 (1906-7): 160.
- (40) FORBUSH, E. H.
On the work of extermination of the gypsy moth. *Mass. Bd. Agr. 41. Ann. Rpt.* (1893): 282.
- (41) FRÉCHOU.
Le black-rot et les vins des vignes traitées. *J. agr. (Barral)*, 24 yr. (1889): 649.

- (42) FRÜHAUF, T., and URSIC, G.
Die Bestimmung sehr geringer Mengen Kupfer. *Bol. soc. Adriatica sc. nat. Trieste*, **10**:103; *through Chem. Centr.*, 3 ser., 19 yr. (1888):198; *Staz. sper. agrar. ital.* (1888):704; *through J. Soc. Chem. Ind.*, **8** (1889):206.
- (43) GALIPPE.
Sur la présence du cuivre dans les céréales, la farine, le pain et diverses autres substances alimentaires. *Compt. rend. soc. biol.*, 7 ser., **4** (1882):726; *Rev. hyg. pol. sanit.*, 5 yr. (1883):23.
- (44) ———
Sur la présence du cuivre dans le cacao et dans le chocolat. *J. pharm. chim.*, 5 ser., **7** (1883):505; *Répert. pharm.*, n. ser., **11** (1883):267.
- (45) ———
Le sulfate de cuivre et le mildew. *J. pharm. chim.*, 5 ser., **15** (1887):430.
- (46) GALLOWAY, B. T.
The grape scare in New York. *U. S. Dept. Agr. Ann. Rpt. for 1891*, p. 375.
- (47) ——— and FAIRCHILD, D. G.
Copper on the fruit at the time of harvest. *U. S. Dept. Agr., Div. Veg. Path. Jour. Mycol.*, **6** (1891):94.
- (48) GARINO, E.
Determination of arsenic in wine made from grapes that had been subjected to cuproarsenical treatment. *Ann. accad. agr. Torino*, **56** (1914):78; *Ann. chim. applicata*, **3**:148; *through Chem. Abst.*, **9** (1915):1526.
- (49) GARMAN, H.
Spraying for codling moth. *Ky. Agr. Exp. Sta. Bull.* 53 (1894):125.
- (50) ———
The use of arsenites on tobacco. *Ky. Agr. Exp. Sta. Bull.* 53 (1894):142.
- (51) ———
Insects injurious to cabbage. *Ky. Agr. Exp. Sta. Bull.* 114 (1904).
- (52) GAUTIER, A.
Sur l'emploi des arsenicaux en agriculture. *Bull. acad. med.*, 3 ser., **59** (1908):229.
- (53) ———
Proc. Acad. Med., Nov. 11, 1913. *Bull. acad. med.*, 3 ser., **70** (1913):370.
- (54) ———
Proc. Acad. Med., Mar. 3, 1914. *Bull. acad. med.*, 3 ser., **71** (1914):300.
- (55) ——— and CLAUSMANN, P.
Origines alimentaires de l'arsenic normal chez l'homme. *Compt. rend.*, **139** (1904):101; *Exp. Sta. Rec.*, **16** (1904-05):489.
- (56) GAYON, U., and MILLARDET, A.
Le cuivre dans la récolte des vignes soumises à divers procédés de traitement du mildew par les composés cuivreux. *Compt. rend.*, **103** (1886):1240; *J. pharm. chim.*, 5 ser., **15** (1887):153.
- (57) GIBBS, H. D., and JAMES, C. C.
On the occurrence of arsenic in wine. *J. Am. Chem. Soc.*, **27** (1905):1484.
- (58) GILLETTE, C. P.
Experiments with arsenites. *Iowa Agr. Exp. Sta. Bull.* 10 (1890):410.
- (59) ———
Notes and experiments upon injurious insects and insecticides. *Iowa Agr. Exp. Sta. Bull.* 12 (1891):536.
- (60) GÜNTHER, A.
Ergebnisse der amtlichen Weinstatistik, Berichtsjahr 1908-1909. *Arb. Kais. Gesundh.*, **35** (1910):1; *Exp. Sta. Rec.*, **24** (1911):267.

- (61) HEIDE, C. VON DER.
Analytische Befunde von Mosten und Weinen aus Trauben der mit Bleiarseniat bespritzten Reben. Ber. Kgl. Lehranst. Wein-, Obst- u. Gartenbau, Geisenheim (1906): 228; Chem. Abst., 3 (1909): 2338.
- (62) HOFFMANN, M.
Ein Beitrag zur Translokation des Kupfers beim Keltern gekupfelter Trauben. Centr. Bakt. Parasitenk., part 2, 4 (1898): 369, 422.
- (63) HOWARD, L. O.
Progress in economic entomology. U. S. Dept. Agr. 1899 Yearbook, p. 146.
- (64) KEDZIE, R. C.
Influence of Paris green on the potato. Michigan Farmer, June 6, 1872.
- (65) ———
The use of poisons in agriculture. Mich. Bd. Health, 3 Ann. Rpt. (1875): 11.
- (66) ———
Mineral residues in sprayed fruits. Mich. Agr. Exp. Sta. Bull. 101 (1893): 19; Exp. Sta. Rec., 5 (1893-94): 793.
- (67) KILGORE, B. W.
On the cause and prevention of the injury to foliage by arsenites, together with a new and cheap arsenite, and experiments on combining arsenites with some fungicides. N. C. Agr. Exp. Sta. Bull. 77-b (1891): 7.
- (68) KINNEY, L. F.
Leaf blight of the pear. R. I. Agr. Exp. Sta. Bull. 27 (1894); Exp. Sta. Rec., 5 (1893-94): 986.
- (69) KRÜGER, F.
Ueber den Einfluss von Kupfervitriol auf die Vergärung von Traubenmost durch *Saccharomyces ellipsoideus*. Centr. Bakt. Parasitenk., part 2, 1 (1895): 64.
- (70) LE BARON, W.
Second annual report on the noxious insects of the State of Illinois (1872), p. 116.
- (71) LEHMANN, K. B.
Hygienische Studien über Kupfer. Arch. Hyg., 24 (1895): 18.
- (72) ———
Hygienische Studien über Kupfer. Arch. Hyg., 27 (1896): 1; Analyst, 21 (1896): 290.
- (73) ———
Hygienische Studien über Kupfer. Arch. Hyg., 30 (1897): 250.
- (74) LIBEŤI, G., CUSMANO, A., MARSIGLIA, T., and ZAY, C.
The presence of copper in tomatoes and tomato preserves. Ann. staz. chim. agrar. sper. Roma, ser. 2, 8 (1916): 163; *through* Bull. Agr. Intelligence, 7 yr. (1916): 662, and Chem. Abst., 11 (1917): 1701.
- (75) LODEMAN, E. G.
The spraying of plants (1896), p. 64, 65. MacMillan & Co., New York.
- (76) LUCET, A.
Proc. Acad. Med., Mar. 3, 1914. Bull. acad. med., 3 ser., 71 (1914): 299, 311.
- (77) McELROY, K. P.
Canned vegetables. U. S. Dept. Agr., Div. Chem. Bull. 13, part 8 (1893).
- (78) McMURTRIE, W.
The influence of arsenical compounds, when present in the soil, upon vegetation. U. S. Com. Agr. Rpt. for 1875, p. 147.

- (79) MACH, E.
Bericht über die Ergebnisse der im Jahre 1886 ausgeführten Versuche zur Bekämpfung der Perenospora. Tirol. Landw. Bl., **6** (1887): 37, 53; *through* Jahr. Agr. Chem. (Hilger), n. ser., **10** (1887): 270.
- (80) MALVY, M.
J. agr. prat., **22** (1911): 293.
- (81) ———
Décret concernant l'importation, le commerce, la détention et l'usage des substances vénéneuses. Bull. intern. repr. fraudes, **9** yr. (1916): 145.
- (82) MARÈS, R.
Les bouillies arsenicales et la lutte contre les altises. Rev. vit., **25** (1906): 426.
- (83) MATHIEU, M.
Recherche de l'arsenic sur les raisins et dans les vins. Ann. fals., **5** yr. (1912): 78; Chem. Abst., **7** (1913): 204; Exp. Sta. Rec., **26** (1912): 841; J. Soc. Chem. Ind., **31** (1912): 295.
- (84) MAYNARD, S. T.
The amount of copper on sprayed fruit. Mass. Hatch Agr. Exp. Sta. Bull. **17** (1892): 38; Exp. Sta. Rec., **3** (1891-92): 865.
- (85) ———
The amount of copper on sprayed fruit. Mass. Hatch Agr. Exp. Sta. Bull. **17** (1892): 39; Exp. Sta. Rec., **3** (1891-92): 865.
- (86) MÉLINE, J.
Instruction pour la vente et l'emploi en agriculture des composés arsenicaux. Bull. intern. repr. fraudes, **9** yr. (1916): 157.
- (87) MESTREZAT, W.
La question du danger de l'emploi des sels arsenicaux en agriculture. J. pharm. chim., 6 ser., **28** (1908): 393; Chem. Abst., **3** (1909): 1569; Exp. Sta. Rec., **20** (1908-09): 959.
- (88) MILLARDET, A.
Ann. soc. agric. Cironde, Apr. 1, 1885, p. 73; *through* The Spraying o Plants, by E. G. Lodeiman, p. 27.
- (89) ———
Sur l'histoire du traitement du mildiou par le sulfate de cuivre. J. agr. prat., **2** (1885): 801.
- (90) ——— and GAYON, U.
Recherche du cuivre sur les vignes traitées par le mélange de chaux et de sulfate de cuivre, et dans la récolte. Compt. rend., **101** (1885): 985; J. agr. prat., **2** (1885): 732.
- (91) MIRMAN, M.
Proc. Acad. Med., Feb. 2, 1909. Bull. acad. med., 3 ser., **61** (1909): 194.
- (92) MOREAU, L., and VINET, E.
L'arseniate de plomb en viticulture. Compt. rend., **150** (1910): 787; Bull. agr. Algérie et Tunisie, **6** (1910): 187; Exp. Sta. Rec., **24** (1911): 168; Ann. chim. anal., **15** (1910): 346; Chem. Abst., **4** (1910): 2539.
- (93) ———
Sur les traitements insecticides en viticulture. Compt. rend., **151** (1910): 1068; Exp. Sta. Rec., **25** (1911): 40.
- (94) ———
L'arseniate de plomb en viticulture et la consommation des raisins frais et des raisins sec. Compt. rend., **151** (1910): 1147; Ann. chim. anal., **16** (1911): 94; Chem. Abst., **5** (1911): 1968; Exp. Sta. Rec., **25** (1911): 40.

- (95) MOREAU, L., and VINET, E.
Comment s'élimine l'arséniate de plomb apporté par la vendange.
Compt. rend., **152** (1911): 1057; Chem. Abst., **5** (1911): 2296.
- (96) MOUREU ET AL.
Sur l'emploi des composés arsenicaux en agriculture considéré au point de vue de l'hygiène publique. Bull. acad. med., 3 ser., **61** (1909): 17;
L'engrais, **24** (1909): 211; Chem. Abst., **3** (1909): 1569.
- (97) MUNSON, W. M.
Report of the horticulturist. Maine Agr. Exp. Sta. Ann. Rpt. for 1891,
p. 106.
- (98) MUTTELET, C. F.
L'arséniate de plomb en viticulture. Ann. fals., 9 yr. (1916): 298; Chem.
Abst., **11** (1917): 684; Exp. Sta. Rec., **36** (1917): 537.
- (99) MUTTELET, F., and TOUPLAIN, F.
L'arséniate de plomb en viticulture. Ann. fals., 5 yr. (1912): 9; Chem.
Abst., **6** (1912): 910.
- (100) ODLING, W., and DUPRÉ, A.
On the existence of copper in organic tissues. Guy's Hospital Reports. 3
ser., **4** (1858): 103.
- (101) O'GARA, P. J.
Presence of arsenic in fruit sprayed with arsenate of lead. Science, n. ser.,
33 (1911): 900; Chem. Abst., **6** (1912): 898; Exp. Sta. Rec., **25** (1911): 642.
- (102) O'KANE, W. C., HADLEY, C. H., and OSGOOD, W. A.
Arsenical residues after spraying. N. H. Agr. Exp. Sta. Bull. 183 (1917);
Exp. Sta. Rec., **38** (1918): 54; Chem. Abst., **11** (1917): 2836.
- (103) ORMEROD, ELEANOR A.
Notes of the season. U. S. Dept. Agr., Div. Ent. Per. Bull., Insect Life,
4 (1891-92): 36.
- (104) PAPASOGLI, G.
Anwendung der Kupfersalze auf die Weinstöcke und hierauf bezugliche
Betrachtungen. L'Orosi, **10** (1887): 369; *through* Chem. Centr., 3 ser.,
19 yr. (1888): 234.
- (105) PENNY, C. L.
Several articles of food known to be healthful found to contain small
quantities of copper. Del. Agr. Exp. Sta. 2 Ann. Rpt. (1889): 172;
Exp. Sta. Rec., **2** (1890-91): 324.
- (106) ———
Copper on grapes. Del. Agr. Exp. Sta. 3 Ann. Rpt. (1890): 149; Exp. Sta.
Rec., **3** (1891-92): 690.
- (107) PERRETT, M.
Le sulfate de cuivre contre le phylloxera et le mildiou. J. agr. prat., **2**
(1885): 630.
- (108) POLACCI, E.
Ueber eine chemische Thatsache, welche beweist, dass Schwefelsaures
Kupfer aus den Trauben nur in ganz geringen Mengen in den Wein
übergehen kann, nebst kritischen Bemerkungen über einige zur Bekämpfung
der Peronospera vorgeschlagene Mittel. Rend. ist. Lombardo,
20: 413; *through* Chem. Centr., 3 ser., 18 yr. (1887): 939.
- (109) POPENOE, E. A., and MASON, S. C.
Second report on the experimental vineyard. Kan. Agr. Exp. Sta. Bull. 28
(1891): 166; Exp. Sta. Rec., **3** (1891-92): 788.

- (110) PORCHET, F.
Les traitements culturaux aux sels d'arsenic et l'hygiène alimentaire.
Trav. chim. alim. hyg. bur. sanit. féd., **1** (1910): 79; Schweiz. Wochschr.,
48 yr. (1910): 694; Chem. Abst., **5** (1911): 754.
- (111) QUANTIN, H.
Sur la réduction du sulfate de cuivre pendant la fermentation du vin.
Compt. rend., **103** (1886): 888; J. pharm. chim., 5 ser., **15** (1887): 39.
- (112) RICHE, A.
Sur les dangers de l'emploi des insecticides à base arsenicale en agriculture.
Bull. acad. med., 3 ser., **59** (1908): 192, 244.
- (113) RILEY, C. V.
Potato pests, p. 67. Orange Judd Co., New York (1876).
- (114) RISING, W. B.
Report of the State Analyst for 1887. Ann. Rpt. Bd. Calif. State Vit. Com.
for 1887, p. 133.
- (115) ROYAL COMMISSION ON ARSENICAL POISONING.
Final Report, p. 36. Eyre and Spottiswoode, London (1903).
- (116) SCRIBNER, F. LAMSON.
Fungous diseases of plants. Rpt. U. S. Com. Agr. for 1885, p. 84.
- (117) SELBY, A. D.
The relation of grape spraying to public health. Ohio Agr. Exp. Sta. Bull.
130 (1902): 42; Exp. Sta. Rec., **14** (1902-03): 61.
- (118) SESTINI, F., and TOBLER, O.
Ueber das Kupfer welches Weine enthalten, die aus mit Kupfersalzen
behandelten Trauben herkommen. L'Orosi, **10** (1887): 289; *through*
Chem. Centr., 3 ser., 18 yr. (1887): 1450.
- (119) SONNTAG, G.
Zu der Verwendung von Arsen und Blei enthaltenden Pflanzenschutzmit-
teln. Arb. Kais. Gesundh., **49** (1914): 502; Chem. Centr., 86 yr. (1915):
450; Chem. Abst., **9** (1915): 1819.
- (120) SPALLINO, R.
Sulla presenza del bario e dell' arsenico nei tabacchi lavorati italiani.
Gazz. chim. ital., 43 yr., part 2 (1913): 475; Chem. Abst., **8** (1914): 787;
Exp. Sta. Rec., **31** (1914): 715.
- (121) SZAMEITAT, A.
Analytische Befunde von Mosten und Weinen aus Trauben der mit Arsen-
verbindungen bespritzten Reben. Ber. Kgl. Lehranst. Wein-, Obst- u.
Gartenbau Geisenheim (1907), p. 176; Exp. Sta. Rec., **20** (1908-09):
1163; Chem. Abst., **3** (1909): 685.
- (122) ———
Vorkommen des Arsens in deutschen Weinen. Ber. Kgl. Lehranst. Wein-,
Obst- u. Gartenbau Geisenheim (1907), p. 180; Exp. Sta. Rec., **20** (1908-
09): 1163; Chem. Abst., **3** (1909): 685.
- (123) TEYXEIRA, G.
Ueber die Behandlung des Liebesapfels (der Tomate) mit Kupferverbin-
dungen. Giorn. farm. Trieste, **2** (1897): 71; *through* Vierteljahr. Chem.
Nahr. Genussmtl., 12 yr. (1897): 286, and Exp. Sta. Rec., **9** (1897-98):
569.
- (124) TROFIMENKO, M., and OBIEDOFF, S.
Le vin des raisins traités aux arseniates. Prog. agr. vit., **65** (1916): 331;
Bull. Agr. Intelligence, 7 yr. (1916): 1023; Chem. Abst., **11** (1917): 2383.

- (125) TRUELLE, A.
L'emploi des composés arsenicaux en arboriculture aux États-Unis.
Bull. soc. nat. agr., **69** (1909): 99.
- (126) ————
L'emploi des insecticides arsenicaux en Angleterre. J. agr. prat., n. ser.,
17 (1909): 268.
- (127) TSCHIRCH, A.
Das Kupfer, p. 133. Ferdinand Enke, Stuttgart (1893).
- (128) VAN SLYKE, L. L.
Analyses of sprayed grapes. N. Y. Agr. Exp. Sta. Bull. 41 (1892): 56;
Exp. Sta. Rec., **4** (1892-93): 55.
- (129) WEED, C. M.
The combination of insecticides and fungicides. Ohio Agr. Exp. Sta.
Bull., Vol. 2, No. 7, 2 ser., No. 14, (1889): 186; Agr. Science, **3** (1889): 263.
- (130) WEISS, M.
Sur l'emploi des composés arsenicaux en agriculture, considéré au point
de vue de l'hygiène publique. Bull. acad. med., 3 ser., **61**, (1909):
140.
- (131) WHEELER, H. J.
Grapes sprayed with Bordeaux. R. I. Agr. Exp. Sta. 4 Ann. Rpt. (1892):
84; Exp. Sta. Rec., **4** (1892-93): 242.
- (132) WHEELER, J. H.
Some pests and diseases of the vine, with remedies. Rpt. 6 Ann. Calif.
State Vit. Conven. (1888): 63.
- (133) WOODS, C. D.
Analyses for poison of apples sprayed with arsenate of lead in mid-summer.
Maine Agr. Exp. Sta. Bull. 224 (1914): 46; Exp. Sta. Rec., **31** (1914):
141; Chem. Abst., **9** (1915): 503.
- (134) ZECCHINI and RAVIZZA.
Copper in wine. Staz. sper. agrar. ital. **16** (1889): 73; *through* J. Soc.
Chem. Ind., **8** (1889): 910.

ADDITIONAL COPIES

OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.

AT

10 CENTS PER COPY



UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1028



Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C.

PROFESSIONAL PAPER

March 13, 1922

APANTELES MELANOSCELUS, AN IMPORTED PARASITE
OF THE GIPSY MOTH.

By S. S. CROSSMAN,¹ *Entomological Assistant, Gipsy Moth and Brown-Tail Moth
Investigations.*

CONTENTS.

	Page.		Page.
Introduction-----	1	Part II.—Introduction and estab-	
Part I.—Description and life his-		lishment—Continued.	
tory-----	2	Abundance of <i>A. melanoscelus</i>	
History-----	2	in Sicily-----	15
Distribution in Europe-----	3	Secondary parasitism in Sicily--	16
Description of species-----	3	Colonization in New England--	16
Methods used in biological work--	4	Methods used to obtain material	
Life history-----	5	for colonization-----	18
Seasonal history-----	11	Success of colonies and distribu-	
Feeding of parasitized larvæ		tion of <i>A. melanoscelus</i> -----	21
versus nonparasitized larvæ--	12	Dispersion-----	22
Longevity experiments-----	12	Secondary parasitism-----	23
Hosts of <i>A. melanoscelus</i> -----	12	The value of <i>A. melanoscelus</i> as	
Part II.—Introduction and estab-		a gipsy moth parasite-----	23
lishment-----	14	Abundance of <i>A. melanoscelus</i> in	
European work-----	14	New England-----	24
Comparison of seasonal history		Conclusion-----	25
in Sicily and New England--	15		

INTRODUCTION.

From the year 1905 to December 1, 1911, the State of Massachusetts and the Bureau of Entomology, United States Department of Agriculture, shared the expenses involved in carrying on an investigation of the natural insect enemies of the gipsy moth (*Porthetria dispar* L.) and the brown-tail moth (*Euproctis chrysorrhoea* L.) in Europe and of the introduction of parasites of these insects from

¹ The writer wishes to acknowledge the efforts of all those who have been connected with the Gipsy Moth Laboratory during the period covered by this report, who have assisted at various times in gathering and recording some of the data from which this bulletin has been prepared. H. A. Preston and C. E. Hood took most of the photographs and W. N. Dovener made the drawing of the adult *Apanteles*. He wishes especially at this time to express his appreciation and thanks to A. F. Burgess, who has general direction of the work, for his help and suggestions.

their native homes to New England. A comprehensive report² of this work from its beginnings through 1910 has been published in Bulletin 91 of the Bureau of Entomology.

Among the imported parasites which are now established is *Apanteles melanoscelus* Ratz., a double-brooded parasite of the gipsy moth. The following report has been prepared in two parts: Part I contains the description of the species and its life history, and Part II takes up its introduction and establishment.

PART I.—DESCRIPTION AND LIFE HISTORY.

HISTORY.

The insect was described by Ratzeburg³ in 1844 very briefly as follows (translation):

Microgaster melanoscelus is so similar to *solitarius* that, since it also has the same mode of life, one might regard it as merely a variety of that species; but it is distinguished not only by the very black femora. . . but also by the third abdominal segment being scarcely rugose, only coarsely punctate at base. Pits at the base of the scutellum very narrow. The one male which I possess is only one line long.

In 1852 Ratzeburg⁴ again mentions this species and gives a record of its being reared from *Porthetria dispar* L. and *Stilpnotia salicis* L.

Reinhard⁵ writes in 1880 as follows:

The specimens called by Ratzeburg (Ich. der Forstinsect. III) *Apanteles melanoscelus*, bred from *Liparis salicis*, are beyond all doubt this species.

Reinhard is here speaking of *A. solitarius* and believes the two to be synonymous. In the same article he places Ratzeburg's type of *A. melanoscelus* in *A. difficilis* (Nees) Reinh. This is undoubtedly incorrect, as the biology of the two parasites is very different.

Marshall⁶ writes in part as follows of *A. difficilis*:

Common. The cocoons are flesh-colored or buff . . .; a few, by some accident, are more yellow. The maggots, on leaving the body of their victim, make separate naked cases, without clustering together. From 1 to 20 issue from a single caterpillar, according to its size.

Dalla Torre⁷ in 1898 also considered *melanoscelus* synonymous with *A. difficilis* (Nees) Reinh.

² HOWARD, L. O., and FISKE, W. F. THE IMPORTATION INTO THE UNITED STATES OF THE PARASITES OF THE GIPSY MOTH AND THE BROWN-TAIL MOTH. U. S. Dept. Agr. Bur. Ent. Bul. 91. 344 p., 74 figs., 27 pl. (1 col.). 1911.

³ RATZBURG, JULIUS THEODOR CHRISTIAN. DIE ICHNEUMONEN DER FORSTINSECTEN, v. 1, p. 74, no. 21. 1844.

⁴ RATZBURG, JULIUS THEODOR CHRISTIAN. DIE ICHNEUMONEN DER FORSTINSECTEN, v. 3, p. 56, no. 51. 1852.

⁵ REINHARD, H. BEITRÄGE ZUR KENNNTNIS EINIGER BRACONIDEN-GATTUNGEN. In Deutsche Ent. Zeitschr., jhrg. 24, heft 2, p. 352-370. 1880.

⁶ MARSHALL, T. A. MONOGRAPH OF BRITISH BRACONIDAE, Pt. 1. In Trans. Ent. Soc. London, 1885, p. 163.

⁷ DALLA TORRE, C. G. DE. CATALOGUS HYMENOPTERORUM, v. 4, BRACONIDAE, p. 168. 1898.

DISTRIBUTION IN EUROPE.

Apanteles melanoscelus is probably present over most of Europe. Specimens have been received at the Gipsy Moth Laboratory from Vienna, Austria; Sicily, Italy; Bendery, Russia; and from Saxony, Brandenburg, Pomerania, and Rhenish Prussia, Germany.

DESCRIPTION OF SPECIES.

It is evident that *solitarius* and *melanoscelus* are closely related, and in time it may be shown that they are the same. If such should prove to be the case, the name *melanoscelus* would have to go, as *solitarius* has the priority. For the present they are to be considered as distinct species, and as Ratzeburg's⁸ description of *A. melanoscelus* is very meager, the following new description has been prepared.⁹

FEMALE.

Length 3 mm. Face feebly shagreened and strongly shiny, with a weak median welt below insertion of antennæ; vertex, temples, and cheeks shagreened, pilose, shiny; mesoscutum shallowly, sometimes indistinctly punctate and shiny; scutellum with the disk very slightly convex, smooth, and polished; mesopleuræ smooth and highly polished, with only a few punctures anteriorly and below, and a conspicuous weakly crenulate depression posteriorly; propodeum rugose except at base, strongly shiny, and with a prominent median longitudinal carina; forewing with stigma large and with the radius very distinctly longer than the transverse cubitus; posterior coxæ large, smooth, and shiny, with a conspicuous flattened area on outer edge at base; spurs of posterior tibiæ equal in length and about half as long as the metatarsus. Abdomen stout; entirely shiny; first tergite broader at apex than at base, rugose punctate; second broad, rectangular, more or less roughened, without distinct lateral membranous margins; third tergite with the rugosity usually confined to the extreme base; remainder of abdomen polished; ovipositor hardly exerted; hypopygium not extending beyond apex of last dorsal segment. Black; antennæ entirely black; tegulæ black; wings hyaline, the stigma dark brown; all coxæ and trochanters black, except sometimes apex of the latter; base of fore femora usually, basal half of middle femora, and most of the posterior femora black or blackish; apical fourth of hind tibiæ and the hind tarsi dusky; sides and venter of the abdomen black. (Pl. I, A.)

MALE.

Essentially as in the female. Differs only in the longer antennæ, in the usually darker legs, and in the basal abdominal tergites being less roughened.

The species is exceedingly close to *A. solitarius* Ratzeburg, but apparently the differences are sufficiently well marked and sufficiently constant to justify holding the two forms distinct. In *A. solitarius* the antennæ are brownish testaceous toward base, the legs, with the exception of the coxæ and the basal trochanters, are practically en-

⁸ RATZEBURG, JULIUS THEODOR CHRISTIAN. OP. CIT. 1844.

⁹ The description and translations of references Nos. 3 and 5 were made by Mr. C. F. W. Muesebeck.

tirely stramineous, and the three basal abdominal tergites are more coarsely rugose, the roughening on the third tergite extending well toward the posterior margin medially; the narrow lateral membranous margins on the apical fourth of the first abdominal tergite are testaceous in *A. solitarius*, while they are piceous black in *A. melanoscelus*.

METHODS USED IN BIOLOGICAL WORK.

As this species hibernates as a maggot within its cocoon, it is a simple matter to gather material during the fall and winter for study in the spring. The cocoons were kept in the laboratory yard during the winter, in cylindrical cages 3 by 8 inches, made of very fine copper netting. Occasionally during the winter a few cocoons were dissected to ascertain the condition of the maggots and to note any changes which might have taken place. As spring approached, the

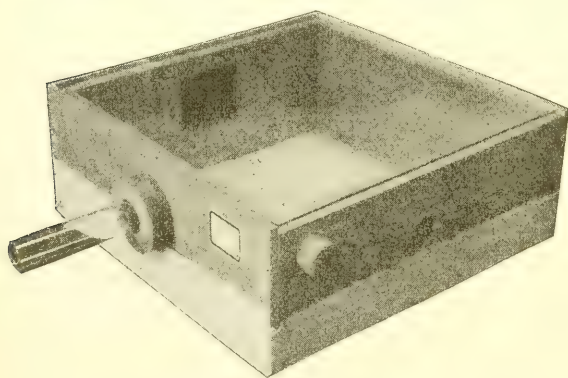


FIG. 1.—Tray with glass top used in life-history experiments with *Apanteles melanoscelus*. (After Culver.)

cocoons were isolated, being placed in small gelatin capsules, or small glass vials $1\frac{1}{2}$ inches by $\frac{1}{2}$ inch. It is necessary to isolate each of the cocoons at this time of the year for two reasons: First, so that one may know the exact age of the adults with which he is

working and keep the males and females separate; second, to prevent any secondary parasites which may issue from the cocoons during the spring from ruining the rest of the *Apanteles* material.

As soon as the *Apanteles* issued they were removed from their containers and placed in glass tubes or glass-covered trays (fig. 1), where they were fed a mixture of equal parts of water and honey. A convenient method of feeding is to dampen a small piece of clean sponge with the food and place it in the tube or tray containing the *Apanteles*. The sponge should be washed out every day or so and dampened again with a fresh mixture of honey and water.

Parasite-free gipsy-moth larvæ were obtained by rearing them from eggs, and a supply was kept in trays protected from parasites ready for use at all times.

Two sizes of glass tubes were found convenient, a small one 4 inches by 1 inch for isolated individuals, and a larger size, 8 by 2

inches, for confining several. As the *Apanteles* are usually active and soon exhaust themselves if allowed to remain in the light, the tubes or cages containing them were kept dark when not in use.

Records of oviposition were obtained in the following manner: A glass tube containing a single female was brought into the light and a parasite-free gipsy-moth larva was introduced on the point of a small camel's-hair brush. As soon as the parasite oviposited in the caterpillar, the larva was removed to a can for rearing. This procedure was continued as long as a female would oviposit readily. As soon as she began to show a lack of interest in the gipsy-moth larvæ, she was returned to the dark to rest and a fresh female given an opportunity to oviposit.

After the first female had rested for an hour or two she was again brought into the light and presented with gipsy-moth larvæ as before. This process was continued with several females throughout their life.

The parasitized larvæ were kept isolated in cylindrical cans, which measured $2\frac{1}{2}$ by 2 inches, there fed, and kept for future study. The structure and length of the various larval instars were determined by daily dissections of these parasitized caterpillars.

LIFE HISTORY.

Apanteles melanoscelus hibernates as a third-stage maggot within its tough sulphur-yellow cocoon. Under field conditions the adults emerge from their cocoons over a period of about three weeks. Emergence is at its height when the gipsy-moth egg hatching is at its maximum, usually during the second week in May. The period of emergence of adults from cocoons kept at the laboratory where all of the cocoons are held under the same conditions is five or six days. The majority of the males emerge during the first four days; the females, beginning to emerge on the second day, continue emerging for four or five days, the bulk of emergence being on the third day after the first appearance of either sex. The adult escapes through a circular hole which it cuts at the anterior end of the cocoon.

Females of *A. melanoscelus* are ready for mating or for oviposition within two or three hours after issuing. They oviposit just as freely whether they have been fertilized or not, and, as is the case with many parasitic Hymenoptera, they often reproduce parthenogenetically.

This species does not copulate readily when enclosed in glass vials or small cages, but was often observed in coition in the large breeding chamber (Pl. V, C). The male approaches the female in the usual state of excitement with its antennæ and wings constantly vibrating. The act of copulation is a matter of a few seconds.

OVIPOSITION.

The act of oviposition takes about one second. The female may alight upon a gipsy-moth larva from flight or walk up to one. In either case the ovipositor is inserted and withdrawn very quickly and practically always an individual egg is deposited. Many larvæ have been dissected after apparent oviposition had been observed and in no case has more than one egg been found from a single oviposition and only rarely have dissections been made which failed to show the presence of an egg. Often the larva attacked thrashes about so violently that it and the parasite fall, but rarely does the parasite fail in its object. After ovipositing in a larva the female usually proceeds to another victim, but occasionally will oviposit a second time before leaving the caterpillar. She apparently does not examine a prospective host but attacks it whether it has previously been parasitized or not. This practice of occasionally placing an egg in a parasitized caterpillar is unfortunate as only very exceptionally will more than one maggot develop within a single host. The parasite favors the posterior half of the caterpillar for oviposition, but will oviposit in any segment of the body.

The females of *A. melanoscelus* which issue from hibernating cocoons prefer to parasitize the first and second stage gipsy-moth larvæ but will oviposit successfully in third-stage larvæ if they are present. When the next or summer generation of adults appear, most of the gipsy-moth larvæ are in the third stage. This is the stage most heavily attacked by this generation, although many fourth-stage caterpillars are successfully parasitized. *Apanteles* females of this generation often attempt oviposition in fifth and sixth stage larvæ but are not so successful, for they are hindered by the long hairs of large larvæ.

There was considerable variation in the number of ovipositions different individuals would make. Between 200 and 300 ovipositions per female were often obtained in these experiments. The greatest number of ovipositions secured by a single female of *A. melanoscelus* was 535. She actually had gipsy-moth larvæ before her for 510 minutes, making these ovipositions a little faster than one a minute.¹⁰ The parasite was allowed several oviposition periods each day and she would parasitize the gipsy-moth larvæ as fast as they were introduced for from 30 to 60 minutes. The first day the periods of oviposition were a little longer than during the following days. This female issued May 23 from its hibernating cocoon, but was not given an opportunity to oviposit until May 27, when

¹⁰ This is about as fast as larvæ can be introduced and withdrawn by the process used. Under more natural conditions, as found in the large breeding chamber, the females were often observed to oviposit 6 or 7 times a minute.

the first gipsy-moth larva was introduced. She worked actively every time she was allowed to do so each day to and including June 2. On the morning of June 3 she was found dead in the tube. A dissection showed that her ovaries still contained about 150 mature eggs and about 200 eggs in different stages of development.

From this and other records, together with notes made from dissections of mature females of *A. melanoscelus*, it seems safe to assume that under natural conditions each female is capable of depositing in the vicinity of 1,000 eggs.

EGG.

The egg at time of deposition averages 0.55 mm. in length and 0.1 mm. in width. It (Pl. I, B) is deposited singly in the body cavity just beneath the skin of the host. It is transparent, with the cephalic end rounded, the caudal end, which is slightly narrowed, bearing a short stock. The chorion appears to be entirely without ornamentation. Development within the egg is rapid and the embryo begins to show form after 15 to 20 hours (Pl. I, C). By this time the egg has widened a little and is slightly shorter than when first deposited. Many eggs have hatched 48 hours after deposition. Just before hatching, the fully developed embryo is plainly seen, often in the position illustrated in Plate I, D. At this time the egg measures 0.7 mm. in length and is greatly swollen around the area which incloses the head. On one occasion an egg, which was ready to hatch, burst while under observation and the larva floated out as illustrated in Plate I, E, after which the eggshell shriveled up considerably.

The length of the egg stage is from 48 to 72 hours, depending on the temperature. If the weather is warm, the majority of the eggs hatch in about two days.

LARVA.

FIRST-STAGE LARVA.

The following measurements are the average for newly-hatched larvæ: Total length, 0.7 mm.; width of head, 0.2 mm.; width of body, 0.1 mm.; length of caudal horn, 0.1 mm.

The freshly-hatched larva (Pl. I, F) is found free in the body cavity. Directly after hatching it may be found in almost any part of the cavity, depending on the point of deposition of the egg. After a few hours it works its way to the dorsal part of the posterior third of the host and usually remains in that area until about ready to issue as a third-stage maggot.

The larva is transparent and extremely delicate, with a large head which is twice the width of the body. The head is composed of a single segment. The labium, labrum, and maxillæ are present. The

sickle-shaped mandibles (Pl. I, J), which are well fitted for tearing, are plainly seen, being in motion much of the time, as the maggot feeds on the lymph and fat bodies of its host. They are 0.08 mm. long, are chitinized throughout, but more heavily so at the tips, and form a good character for distinguishing this stage from the following ones. The body is made up of ten segments at this period, but later has eleven after the tenth segment divides. On the dorsum the maggot has a systematic arrangement of short, rather stiff, backward pointing spines. The spines are located as follows: Two each on the second and third segments, four on the fourth segment, six each on the fifth to ninth segments inclusive, and eight on the tenth segment. It seems likely that these spines assist the maggot in working its way to the caudal end of the host.

The anal vesicle, which is common to the microgasterine larvæ, is prominent and the caudal horn is seen just beneath the evaginated anal vesicle.

As the larva matures, the heart, nervous system, and silk glands can be distinguished, but no evidence of the tracheal system is apparent.

When ready to molt the larva has increased in length to nearly 2 mm. and the body has widened in proportion, except the head, which remains about the same width throughout the stage.

The larva remains in this stage from two to three days in the spring generation and from six to eight days in the summer generation.

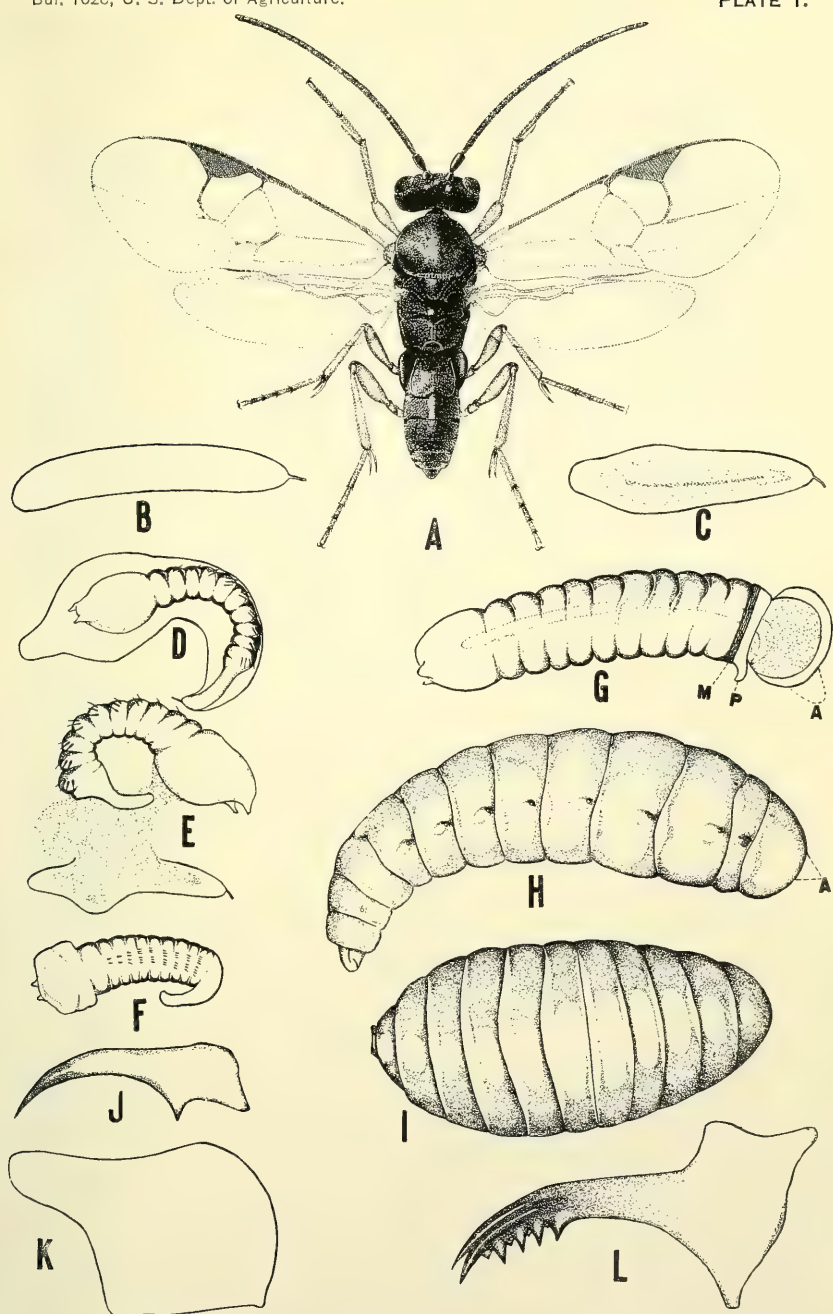
SECOND-STAGE LARVA.

In molting the head skin of the first-stage maggot is split off and is occasionally found in the body cavity of the host, closely associated with the cephalic region of the second-stage larva. The remainder of the molt skin is worked back to the last body segment (Pl. I, G at M).

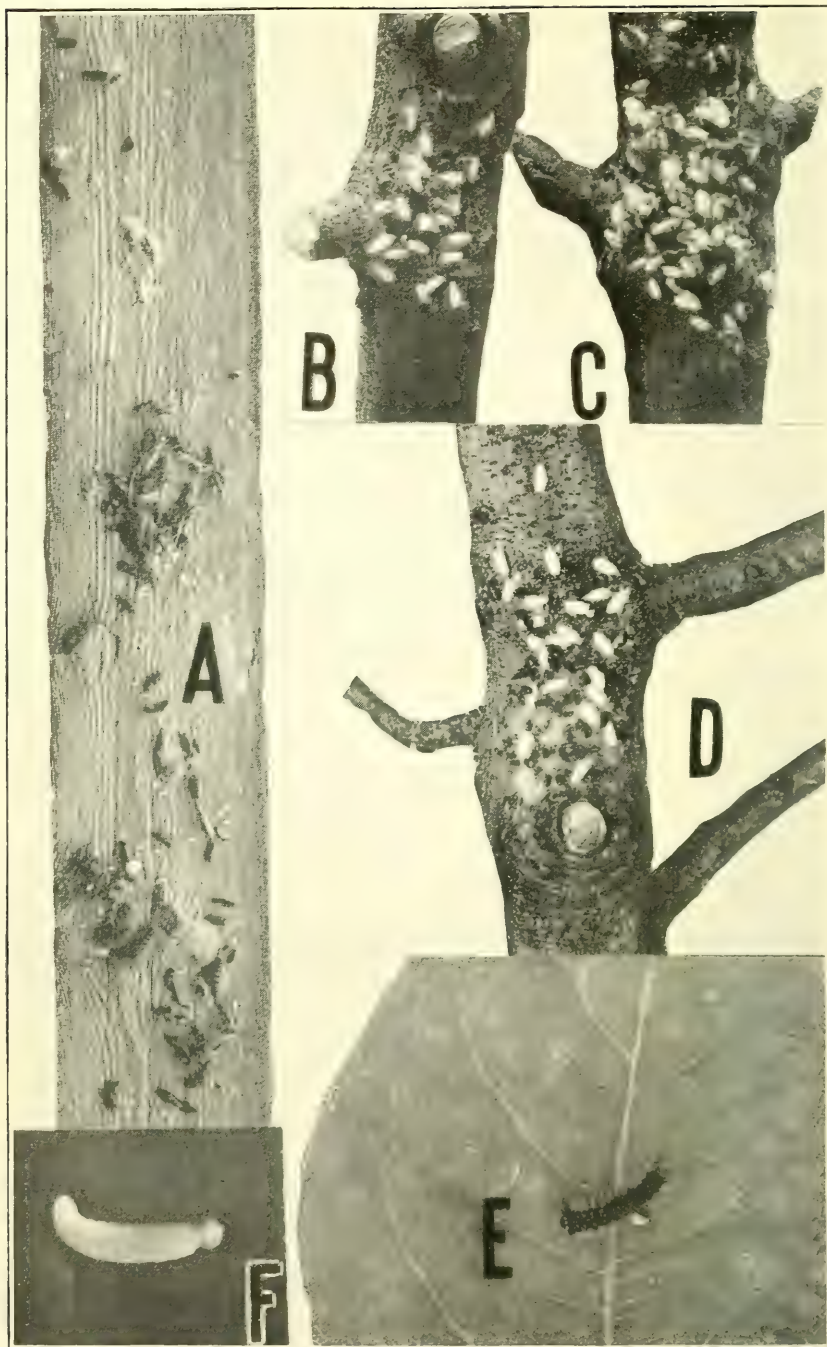
The second-stage maggot is usually found dorsally in the caudal end of the host in the body cavity, its head toward the posterior end of the caterpillar and its body resting longitudinally. When first molted it measures about 2.75 mm. in length and 0.55 mm. in width, the head and body being approximately the same width.

In contrast to the first-stage maggot the body is entirely destitute of spines and the mouthparts are poorly developed. The mandibles (Pl. I, K) are not fitted for tearing or biting, but are soft, fleshy forms without chitin and are very difficult to locate.

The anal vesicle is still present and is more prominent than in the previous stage (Pl. I, G at A). The caudal horn is present but has not grown with the developing maggot and appears very small in comparison with the size of the larva (Pl. I, G at P).

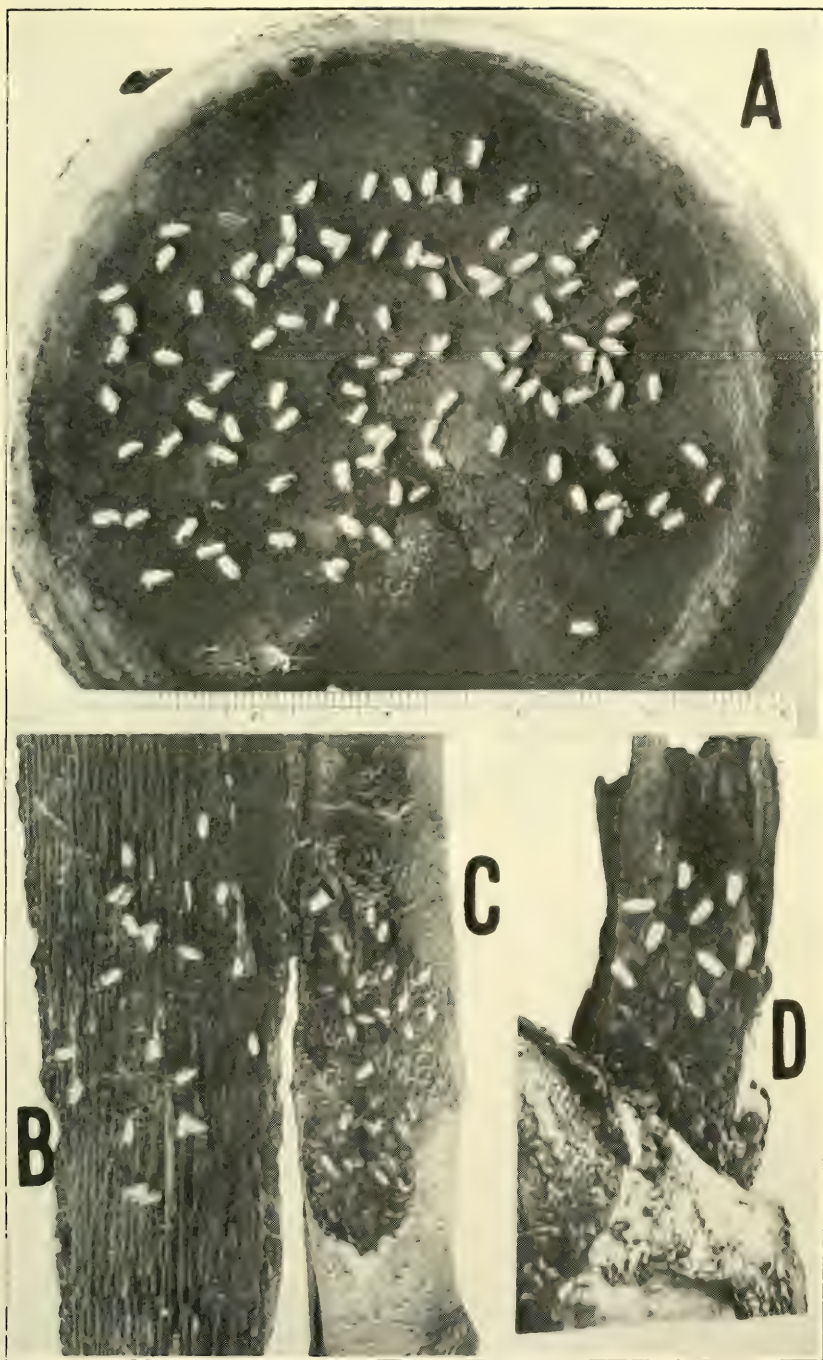
**APANTELES MELANOSCELUS.**

A, adult female; *B*, egg, dissected from female; *C*, egg, after 15 to 20 hours in host; *D*, egg, after 48 hours in host; *E*, first-stage larva and shriveled eggshell from which it came, 50 hours after oviposition; *F*, first-stage larva; *G*, second-stage larva; *m*, molted skin, *p*, caudal horn, *a*, anal vesicle; *H*, third-stage larva, dissected from host; *a*, anal vesicle; *I*, third-stage larva, hibernating form, dissected from cocoon; *J*, first-stage larval mandible; *K*, second-stage larval mandible; *L*, third-stage larval mandible. All much enlarged.



APANTELES MELANOSCELUS.

A, Hibernating cocoons on board found in Melrose, Mass., 1917; *B*, first-generation cocoons on branch collected at Quincy, Mass., 1920; *C*, first-generation cocoons on branch collected at Melrose, Mass., 1916; *D*, first-generation cocoons on branch collected at Quincy, Mass., 1920; *E*, third-stage maggot two-thirds of its way out of fourth-stage gipsy-moth larva; *F*, third-stage maggot dissected from host, anal vesicle still evaginated.



APANTELES MELANOSCELUS.

A, Hibernating cocoons on underside of vessel collected at Weymouth, Mass., 1920; *B*, hibernating cocoons on underside of bark collected at West Boylston, Mass., 1920; *C*, hibernating cocoons on underside of branch collected at Hingham, Mass., 1920; *D*, hibernating cocoons on stump collected at Melrose, Mass., 1916.

The heart, nervous system, and silk glands are more pronounced, especially the latter, which are coiled and recoiled and appear to fill much of the body cavity. Traces of the tracheal system are observed during the last part of the stage.

Development is rapid and in two or three days the maggot has increased in size to 4.5 mm. long and 1 mm. wide.

The average period spent in this stage by the first-generation larva is from two to three days and for the second generation from five to seven days. Just before molting the mandibles of the third-stage maggot can be seen.

THIRD-STAGE LARVA.

The period spent by the third-stage maggot (Pl. I, H) within its host varies from a few hours to two days with the spring generation and as long as three days with the summer generation. When a second-stage maggot is about ready to molt it usually works its way to the central part of its host and molts there, although occasionally third-stage larvæ are found in the caudal end of the caterpillar. Just before issuing the maggot is 5 to 7 mm. long, is slender, and tapers toward the anterior end; it is dull white and dorsally is sparsely covered with very fine, inconspicuous hairs. At the caudal end of the body the anal vesicle is still evaginated (Pl. I, H at A; Pl. II, F). The body is apparently filled with the silk glands and has a well-developed tracheal system, with eight pairs of spiracles visible. There is a pair on the second segment and a pair on each of segments 4 to 10, inclusive. The spiracles are very tiny and difficult to determine, the last seven pairs being associated with laterally protruding areas. On the eleventh segment there is a slight protruding area laterally which may contain a spiracle, but one was not observed on this segment. The mouthparts are plainly visible, consisting of labium, labial palpi, labrum, maxillæ, maxillary palpi, and mandibles. The mandibles (Pl. I, L), which are 0.26 mm. long, are strong and well fitted for tearing. They are slightly curved anteriorly. The tip is divided into two sharp teeth. The anterior third of the mandible appears to be double with two biting edges, each edge armed with several teeth. There are dorsally on this part of the mandible two elevations which appear to strengthen the organ. The tips and points of the teeth are more heavily chitinized than the rest of the mandible.

When ready to issue the maggot tears a hole in the side of the caterpillar, usually in the fifth or sixth segment. When it has issued to about two-thirds its length it begins to form its cocoon (Pl. II, E). By the time the larva is entirely out, the anal vesicle has been invaginated. If the larva is of the spring generation, it voids the accumulated waste material of the larval stages after 18 to 20 hours in the cocoon. In about two days after completion of the

cocoon the maggot pupates and casts its larval skin, which is pushed back to the posterior end of the cocoon over the previously voided material.

The third-stage maggot (Pl. I, I) of the summer generation has quite a different cycle. After having completed its cocoon, in which it is to hibernate, it becomes shorter and stouter, measuring about 4 mm. in length. It is a pale lemon yellow, and remains quiescent until the following spring. About the time when the first gipsy moth eggs hatch, the maggot resumes activity, first voiding the accumulated waste in the caudal end of the cocoon. Two or three days later pupation takes place, and the larval skin is cast and pushed to the caudal end of the cocoon, as in the spring generation.

PUPA.

The pupal stage lasts from five to nine days. About two days after the completion of the cocoon the larval skin is cast. The pupa is whitish with long appendages and has a movable abdomen. The eyes soon begin to darken, the ocelli are distinguishable, and the thoracic and abdominal segments take form. The mouth parts, antennæ, legs, and recurved ovipositor are plainly seen. In three or more days the development is complete. The whole is now dark, nearly black. The pupal skin is cast and the adult lifts the cocoon cap, having cut around its base, which was left weak by the spinning larva.

COCOON.

When the third-stage maggot is about two-thirds of its way out of the host, it begins to construct its cocoon. The first few threads seem to be attached ventrally to the maggot itself on the last segment which is outside of the caterpillar. After making an attachment at this point the maggot straightens out horizontally, then swings back underneath itself again and makes another attachment. It continues this process laterally and dorsally, spinning all the while and forming loops which it gradually fastens securely in a similar manner. As the outer loose cocoon is developed, the maggot must break away from the original attachments and gradually work itself entirely free from its host. The maggot reverses its position several times during the construction of the cocoon. When completed, the cocoon is about 5mm. long and is composed of an outer loose covering of fine threads, some of which are attached to the host or any object on which it may rest. Just within this is a tough, tightly woven envelope, which encases a very fine smooth inner sac next to the maggot. The cocoon is slightly flattened on its ventral surface and convex laterally and dorsally. The anterior end is rather flat. The cap, which is thinner along its base, is at the anterior end. The posterior end is slightly pointed. It takes the spring-

generation maggot about two hours to form its cocoon and the summer maggot three to four hours to complete the cocoon in which it is to hibernate.

The cocoon made by the spring-generation maggot is pale yellowish white, a little smaller and rather delicate as compared with the hibernating cocoon, which is a light sulphur yellow and very tough.

LOCATION OF COCOONS.

The cocoons of the spring generation are found singly or in clusters, depending upon the degree of gipsy moth infestation and the abundance of *Apanteles*. In low growth the cocoons are very apt to be found on the foliage and often on the débris on the ground, as well as along the trunk and small branches. On large trees a few cocoons are found on the foliage, but if abundant the majority are located at the junction of the smaller branches on the underside. The cocoons are attached lightly, often on top of others and invariably a dead second-stage gipsy moth larva is found with each cocoon (Pl. II, B, C, D). After the adults have issued these cocoons are easily washed or blown from the trees and are seldom found the next spring.

The second-generation cocoons are found securely attached scatteringly over the tree trunk and in clusters under the larger limbs where the gipsy-moth larvæ congregate. These cocoons are not often found on the foliage.

The gipsy-moth larvæ, when parasitized by the second generation of *Apanteles melanoscelus*, have a tendency to crawl to protected and out-of-the-way places just before the issuance of the parasite maggots. The cocoons are often associated with the gipsy-moth pupæ and larger caterpillars. They are found behind billboards and signs, attached to trees (Pl. III, D), on the undersides of boards on the ground (Pl. II, A), under fence rails or rocks, under loose bark, and on rough surfaces on the underside of limbs (Pl. III, B, C). Plate III, A, shows a tin vessel found during the summer of 1920 in a dump at Weymouth, Mass., and illustrates the habit of parasitized larvæ of crawling to hidden places. There are a few over 100 cocoons on the bottom of this vessel, and there is a cluster of 25 cocoons on one side of the vessel not shown in the photograph.

SEASONAL HISTORY.

The seasonal history varies considerably with the season. The issuance of adults of *Apanteles melanoscelus* from their hibernating cocoons begins about the time of maximum hatch of the gipsy-moth eggs, which is usually near the middle of the second week in May. During such a season most of the *Apanteles* will have issued by May 20. Under field conditions females of *Apanteles melanoscelus* do not

begin to oviposit immediately, for the bulk of issuance of the spring generation parasite maggots is around June 12. The adults which develop from these maggots will be found issuing from 7 to 11 days later. Cocoons of the second generation, or those in which the parasite is to pass the winter, begin to appear about the fourth of July, but usually not in abundance until the second week in July.

FEEDING OF PARASITIZED LARVÆ VERSUS NONPARASITIZED LARVÆ.

Several feeding records were kept of gipsy-moth larvæ which were known to be parasite-free as checks against similar feeding records of larvæ in which *A. melanoscelus* had oviposited. The records show that healthy gipsy-moth larvæ eat from two to three times as much as those which contain parasite maggots. These data were obtained from feeding records made during the period between oviposition in the caterpillar and issuance of the parasite maggot and the checks were kept only for a similar number of days. The gipsy-moth larva from which a maggot of *A. melanoscelus* has issued eats no more, although it may live a few hours or as long as two weeks, the average being seven days.

LONGEVITY EXPERIMENTS.

The tray shown in figure 1 (p. 4) was found most satisfactory for the longevity experiments although glass tubes 8 by 2 inches were used successfully for small numbers of parasites.

The adults were fed on an equal mixture of honey and water, sprayed on small pieces of sponge. It is important that the sponges should be kept clean by thoroughly washing every other day. Nothing but the food was inclosed in the trays with the adults, but in the tubes they did better if a crumpled bit of paper was present on which the parasites might rest and clean themselves. *A. melanoscelus* in the tubes and trays, if kept in the light, lived for about one week. When the containers were kept darkened by means of black paper, the parasites remained rather inactive much of the time, and lived considerably longer.

In several experiments with adults issuing in spring and summer, males and females lived for 30 to 32 days. In one case a female of the summer issuing generation lived 35 days. There was very little difference in the length of life of the adults, the females living slightly longer than the males. Without food they were able to live only a few days.

HOSTS OF *A. MELANOSCELUS*.

Ratzeburg¹¹ gives as hosts in Europe *Porthetria dispar* L. and *Stilpnotia salicis* L.

From field-collected material in this country *A. melanoscelus* has been reared only from the gipsy moth. *S. salicis*, the satin moth.

¹¹ RATZEBURG, JULIUS THEODOR CHRISTIAN. OP CIT. 1852.

recorded as a host of this parasite in Europe, was not found in America until the latter part of June, 1920, when a heavy infestation was discovered at Medford, Mass. When the infestation was found the larvæ were from half to full grown and rather too large to be expected to harbor *A. melanoscelus* maggots. Collections of larvæ were made immediately, but no *A. melanoscelus* were reared. On several occasions, however, cocoons of this species were found on tree trunks closely associated with belated larvæ of *Stilpnotia salicis*, and there is very little doubt that these cocoons were spun by *A. melanoscelus* maggots which had issued from the near-by small and inactive larvæ of *S. salicis*. It is known that with the gipsy moth the larvæ from which *A. melanoscelus* maggots issue do not die for several days. They are rather inactive and often do not move far from the place where they were when the parasite issued.

In August, 1920, an outbreak of *Hemerocampa leucostigma* S. & A. was located in a small area in Somerville, Mass. This is the first time since *A. melanoscelus* has been established that larvæ of the white-marked tussock moth could be collected in eastern Massachusetts, except very sparingly. The season was too far advanced to expect to rear *A. melanoscelus* from collected material, and none were recovered from larvæ brought to the laboratory. It was apparent, however, from observations made at the infestation, that this parasite had been responsible for the untimely death of very many tussock-moth larvæ, for the cocoons of *A. melanoscelus* were abundant on the sheathing of near-by houses where the tussock-moth larvæ had gathered in large numbers and were spinning their cocoons.

Several experiments were tried confining adults of *A. melanoscelus* with various larvæ. Reproduction was successful with *Malacosoma americana* Fab., *M. disstria* Hübn., *Hemerocampa leucostigma* S. & A., *Olene basiflava* Pack., and *Euproctis chrysorrhoea* L. The female attacked all but the last eagerly. Oviposition apparently took place in *Charidryas nycteis* D. & H., *Hemileuca maia* Dru., *Pteronius ribesii* Scop., and in a species of tortricid. All of these larvæ died and were dissected. Several maggots of *A. melanoscelus* were found in the larvæ of *C. nycteis*, but no evidence of parasitism was found in the other larvæ.

Several larvæ of *Stilpnotia salicis* were presented to females of *A. melanoscelus*. No oviposition was recorded. This was late in the season and the larvæ had matured much beyond an attractive stage for oviposition by this parasite.

Some six or seven species of smooth-skinned or hairless larvæ have been confined with females of *A. melanoscelus* but rarely have they shown any attention to them. This parasite evidently will attack quite a number of small hairy lepidopterous larvæ when the oppor-

tunity presents itself, but shows very little interest in large hairy caterpillars or in larvæ which are destitute of hair or only sparsely covered.

PART II.—INTRODUCTION AND ESTABLISHMENT.

EUROPEAN WORK.¹²

In January, 1911, Mr. W. F. Fiske, who was at that time in charge of the parasite work under the direction of Dr. L. O. Howard, Chief of Bureau, sailed for Italy to investigate the parasite situation. The main object at that time was to make a study of conditions there and to attempt to introduce on a large scale *Chalcis flavipes* Panz., a pupal parasite of the gipsy moth. Headquarters were located at Naples and a vacant building was rented and fitted up for use as a laboratory near the School of Agriculture at Portici.

Early in February, 1911, Mr. Fiske visited several places in Sicily to ascertain the field conditions and degrees of gipsy moth infestation preliminary to obtaining the *Chalcis* material. While there he discovered that cocoons of a species of *Apanteles* were present in "countless thousands." This came very much as a surprise, and he determined to put most of his energies, even at the expense of previous plans, into an effort to send this parasite to America in as large numbers as possible.

The localities, a forest at San Pietro, Caltagirone, and the forests back of Barcellona, in Sicily, were situated where the gipsy-moth larvæ and cocoons were sufficiently abundant to warrant the collection of either in large numbers. Both places were some distance from a railroad, and the location which gave more promise was the less accessible of the two. As soon as the gipsy-moth larvæ had hatched and were of sufficient size to have been parasitized, collections of larvæ were begun. A foreman and crew were located at each place, and the collections of larvæ were started. The first larval collection arrived from Caltagirone at Portici on May 14, and a few cocoons were present at that time. When the collections arrived at Portici they were placed in trays in the house which was rented for that purpose. About a dozen Italian girls took care of the trays—that is, fed the caterpillars, removed the parasite cocoons daily, and kept the trays clean. These girls were very adept at this work, being familiar with the care of silkworms and having assisted in handling alfalfa weevil parasite material for shipment to America.

As soon as the cocoons were removed from the trays they were placed in cold storage to prevent the further development of the parasites.

¹² The part of this report pertaining to European work is based on the correspondence of Mr. W. F. Fiske while in Europe.

The tray work was supplemented by collections of the cocoons in the field and these had to be iced to prevent as much as possible any issuance of secondary parasites, as well as to retard the development of the maggots of *Apanteles melanoscelus*. When the cocoons arrived at Portici they were usually picked over and repacked, although it was not possible to do this in all cases.

The shipments depended largely on the supply of parasite material on hand and the dates of departure of vessels to America; but the policy followed was to ship as often as possible.

Several types of containers were used for transporting the cocoons, all of which came in the vessels' cold storage and all proved quite satisfactory. One type of refrigerator was so made that the small packages of cocoons of *Apanteles* in the inner chamber were entirely surrounded by ice. This refrigerator was a double-walled affair and rather expensive to construct. It was inclosed in a box of sawdust. Another type was a sort of ice-cream freezer arrangement consisting of two metal water-tight cylinders, one within the other, with the cocoons in containers packed in sawdust within the inner cylinder. Ice was packed between the two cylinders and the whole was packed in sawdust in a large wooden box. At the bottom of the outer cylinder was a small pipe which went through the box and allowed the water to drain off. On some occasions the containers were repacked with ice in New York before being forwarded to Melrose. A few shipments of cocoons which were merely packed in boxes, and kept in cold storage for as much of the trip as possible, came through in good condition.

COMPARISON OF SEASONAL HISTORY IN SICILY AND NEW ENGLAND.

The spring of 1911 was cold, rainy, and rather backward in Sicily. By May 15, however, parasite maggots had begun to issue from the gipsy-moth larvæ. The earliest record for issuance of maggots for New England is May 22. It is likely that during many seasons in Sicily maggots issue by May 7, whereas the New England record referred to is an early one, issuance of maggots usually beginning the last of May. This would make the season in Sicily about three weeks earlier than at Melrose Highlands, Mass. The second-generation cocoons were being collected in Sicily by June 10, 1911, but June 23 is the earliest record of the presence of this generation in New England.

ABUNDANCE OF *A. MELANOSCELUS* IN SICILY.

The parasite cocoons were very abundant in places as indicated in notes and correspondence received from Mr. Fiske.

Apanteles killed more caterpillars than all of the other parasites put together. Cocoons average 1,000 to a tree, not counting the smaller trees.

Notes made at another place state:

Apanteles exceedingly common. Estimate 75 per cent control on average and higher in some places. Estimate 10,000 cocoons on one large tree.

To illustrate the abundance of cocoons, those present on an area the size of a man's hand were counted and the number found was 187. Mr. Fiske states that there were more over a similar area high up on the tree. The same day he visited another place and found conditions similar.

SECONDARY PARASITISM IN SICILY.

Apparently the first-generation cocoons are not attacked seriously by secondaries, probably less than 10 per cent being killed. Secondary parasitism of the hibernating cocoons is very heavy, and one note was found referring to a location where it was feared that it would almost exterminate the parasite. Sometimes as high as 75 per cent of the cocoons from Sicily received at the laboratory and wintered were killed by secondaries.

COLONIZATION IN NEW ENGLAND.

During the rush of the season's work it was supposed that two or three species of Apanteles were represented and the importation and colonizations were recorded in correspondence and in the notes as *A. solitarius* and Apanteles II and III. The confusion was not at all surprising for there were two and possibly three species represented, but the fact of the matter, as it appears at the present time, is that the adults liberated during June, 1911, at North Saugus, Mass., from cocoons imported from Sicily as *A. solitarius*, were adults of the first generation of *A. melanoscelus*; and that the cocoons received later in the summers of 1911 and 1912, which were hibernated at the laboratory, and the adults from which were liberated at Melrose during the springs of 1912 and 1913, were cocoons of the second generation of *A. melanoscelus*.

During June, 1911, about 125,000 cocoons of the first generation were received from Europe, and every precaution was taken to prevent the escape of any secondaries which might be present. As soon as they were received at the laboratory they were taken to North Saugus, Mass., and immediately placed in darkened containers from which nothing could escape except by entering glass tubes, where they were inspected, the good allowed to escape and the bad destroyed. In this manner 23,000 adults were liberated during June and July, 1911. During the months of July and August, 1911, nearly 17,000 hibernating cocoons were received. These were isolated at the Melrose Highlands laboratory, each one being placed in a small gelatin capsule and then wintered under outdoor conditions.

is

al

re

re

in

5.

ld

es.

r-

of

at

1,

m

ig

1

er

es.

1

1

3

11

7

16

2

21

63

w

in

re

s.

w

in

ts

m

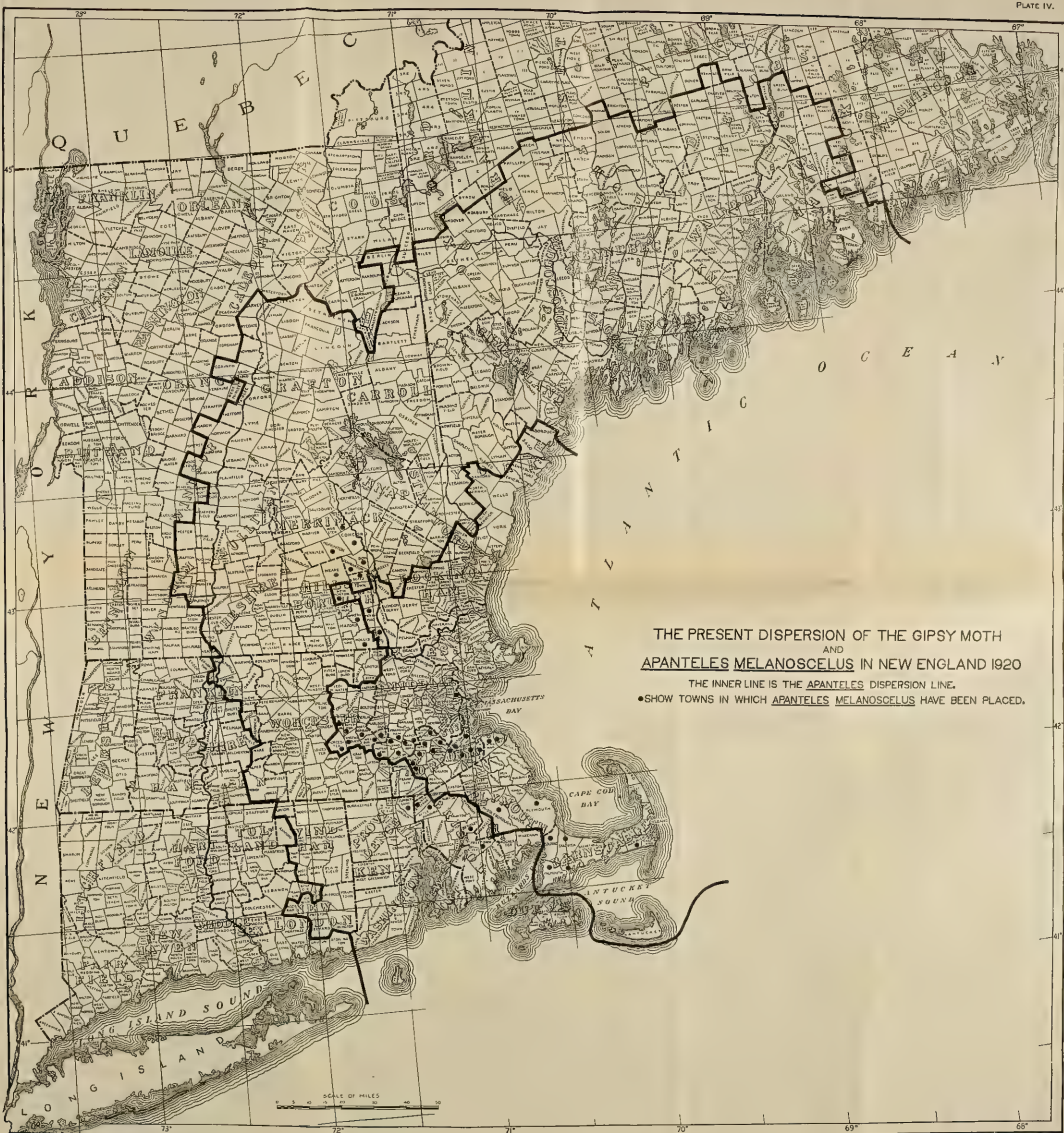
us

ls

p-

h

re



THE PRESENT DISPERSION OF THE GIPSY MOTH
AND
APANTELES MELANOSCELUS IN NEW ENGLAND 1920

THE INNER LINE IS THE APANTELES DISPERSION LINE.

• SHOW TOWNS IN WHICH APANTELES MELANOSCELUS HAVE BEEN PLACED.

During the spring of 1912 the adults which issued from these cocoons were liberated near the laboratory.

Early in 1912 Mr. Fiske again went to Italy, this time with several assistants. As one of the results of this trip, 22,000 cocoons of the second generation of *A. melanoscelus* were received during the summer of 1912. These cocoons were collected in the forest of San Pietro, near Caltagirone, Sicily, during the week beginning June 15. They were shipped to Naples in cold storage on June 22 and held there in cold storage until all had been isolated in gelatin capsules. Early in July they were sent to America in cold storage and hibernated at the laboratory. The adults which issued in the spring of 1913 were liberated at Melrose.

Table 1 shows the number of individuals of *A. melanoscelus* that have been liberated in New England. The colonizations of 1911, 1912, and 1913 were adults which issued from cocoons received from Sicily; the rest of the colonization material was obtained by rearing and breeding New England material.

TABLE 1.—Number of *A. melanoscelus* liberated in New England, 1911–1920.

Year.	Number of adults liberated, Sicilian material.	Cocoons colonized, New England material.	Number of colonies placed in Massachusetts.	Number of colonies placed in New Hampshire.	Number of colonies placed in Rhode Island.	Total number of colonies.
1911.....	23,000	.....	1	.....	.....	1
1912.....	203	.....	1	.....	.....	1
1913.....	273	.....	1	.....	.....	1
1915.....	.....	1,500	2	.....	.....	3
1916.....	.....	5,541	11	1	.....	11
1917.....	.....	3,500	7	.....	.....	7
1918.....	.....	8,100	9	7	.....	16
1919.....	.....	8,930	2	.....	.....	2
1920.....	.....	10,100	11	9	1	21
Total.....	23,476	29,671	45	17	1	63

As will be seen from a study of the figures in Table 1, very few adults were liberated in 1912 from the 17,000 cocoons received in 1911, and in 1913 from the 22,000 cocoons received in 1912. The poor issuance from these imported cocoons was due to several factors. Fifty to seventy-five per cent were killed by secondaries and a few were injured while being collected. These cocoons were kept in gelatin capsules from the middle of the summer until the adults issued the following spring. Subsequent experiments have shown that the mortality of hibernating larvæ of *Apanteles melanoscelus* was not so high when the cocoons were isolated in small glass vials plugged with cotton batting as when they were kept in gelatin capsules. An examination of dead maggots of *A. melanoscelus*, which had been isolated in gelatin capsules, showed that the maggots were

very dry and shriveled, and indicated that death might have been due to lack of moisture within the capsules.

No colonies were liberated in 1914, as no importations were made and the parasite had not been sufficiently well established to furnish colonization material.

All *Apanteles melanoscelus* liberated since 1913 have been put out while in the cocoon and have been of the summer-issuing generation. Most of these colonies have contained 500 cocoons. In liberating a colony the cocoons are taken to the field and emptied into a small cylindrical can, which is then nailed to a tree in an inconspicuous place. A cover is placed on the can to protect the cocoons from rain and birds. The adults escape through three $\frac{1}{4}$ -inch holes punched in the can near the top. The size of the can is not especially important, but a convenient can used at the laboratory is 3 inches in height and 2 inches in diameter. It is necessary to place a band of tree-banding material entirely around the can to prevent ants from destroying the colony.

In selecting sites for colonies, woodland areas with a light to medium gipsy-moth infestation are preferable. Heavily infested territory which is apt to be stripped of its foliage should be avoided.

After the colony has been liberated a roadside tree is marked in white paint with an arrow pointing to the colony and the letters A. M. In the woodland near the exact spot of the colony a tree is banded with white paint. These field marks are made so that the place can be found later if desired. At the same time a numbered note is written for the laboratory files which explains the condition at the colony site and gives directions for finding the colony.

The colonies have been placed in groups of towns, one colony in each town, as shown in the accompanying map (Pl. IV). This method of liberating colonies was used because the parasite disperses rapidly and there was considerable chance that small colonies would not become established if they were placed singly at widely separated locations. In this way several rather large areas, from which the parasite can spread to the surrounding towns, have become well stocked.

METHODS USED TO OBTAIN MATERIAL FOR COLONIZATION.

The story of the introduction of *A. melanoscelus* and the colonies liberated from the imported material has been recorded earlier in this paper. Two methods have been used to get material for colonization since the establishment of the parasite in New England—first, by rearing the parasite from field-collected gipsy-moth larvæ, and, second, by breeding the parasite at the laboratory.

The first method consists merely of making collections of large numbers of second-stage gipsy-moth larvæ from locations where the parasite is present in sufficient numbers to warrant such collections.

These larvæ are placed in trays and fed until the parasite maggots issue. The maggots, upon issuing, spin their cocoons, usually attached to the caterpillar or to the object on which the host was resting at time of issuance. Each day the gipsy-moth larvae are fed, the trays cleaned out, and all of the parasite cocoons removed. The cocoons are put up in lots of 500 and kept in a refrigerator until they are placed in the field. They are colonized as soon after removal from the trays as possible, usually on the following day. Occasionally it has been necessary to keep the cocoons in the ice chest five or six days, and this has been done without any apparent injury to the parasite.

The second method of securing material for colonization may be divided into two parts, namely, the fall work which consists of gathering and caring for the hibernating cocoons, and the actual breeding work which is carried on in the spring. There is a great mortality of wintering *A. melanoscelus*, largely due to secondary parasitism, and a large number of cocoons must be gathered in order to have a few adults of *Apanteles* in the spring to start the breeding work. The cocoons are collected as soon as possible after they have been found, in an endeavor to get them before the secondaries or ants do.

From 10,000 to 20,000 cocoons are collected during July from places where the parasite is abundant. Some of the secondaries present at this time hibernate within the cocoon, but there are many which have one or more generations during the early fall.

For a number of years these cocoons were isolated in gelatin capsules as soon as they arrived at the laboratory. This prevented the issuing secondaries from doing any further damage, but it was found that the spring issuance of *A. melanoscelus* from apparently good cocoons was exceedingly small. This was due partly to secondaries which hibernate within the cocoons, partly to injury while handling, and considerably to the drying of the maggots of *A. melanoscelus* in the cocoons. The last two years the cocoons have not been isolated, with the result that a better spring issuance has been obtained. Instead of isolating the cocoons they were separated into lots of 100 each and placed in glass tubes 1 by 4 inches, which were plugged with cotton batting. These tubes were then placed on a background of white in a warm bright place where they could be watched and the secondaries were removed as fast as they issued. Most of the secondaries issuing in the summer leave the cocoons within two weeks after collection, although a few continue to issue for two weeks longer. After the secondaries have stopped issuing the cocoons are picked over and the empty ones and those showing external injury are discarded. Many of the cocoons which contain hibernating secondaries at this time can be distinguished by a slight discolored spot on the cocoon; such cocoons also are destroyed. The

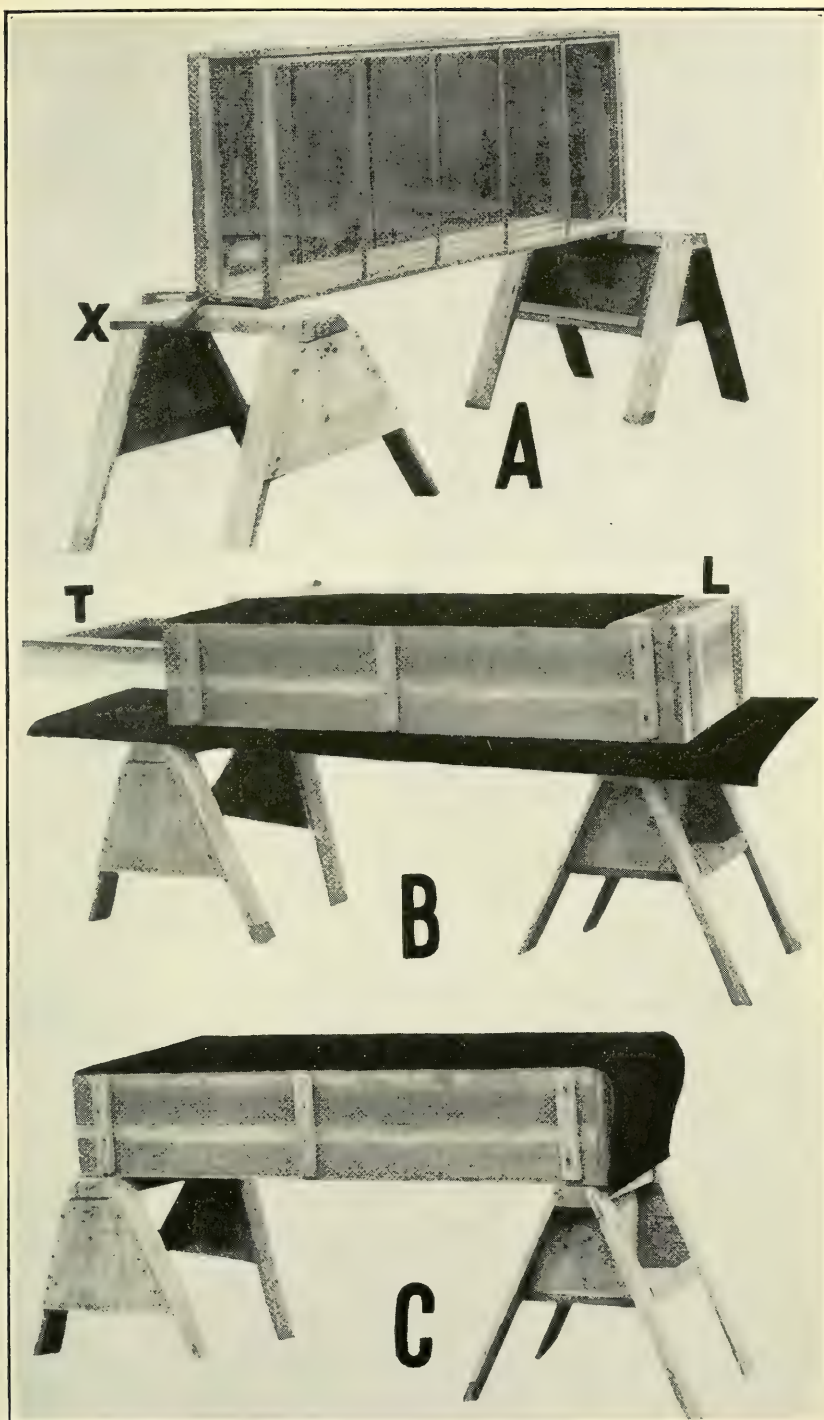
remaining cocoons are placed in bulk in a fine copper-wire cage which is nailed in a protected place in the yard until spring.

The spring work begins during the last of April when the cocoons are removed from their hibernating cage and isolated for a short period in capsules. They are isolated at this time for convenience in handling the adults of *Apanteles* and destroying the wintering secondaries which issue. The cocoons are isolated in the capsules less than two weeks before *A. melanoscelus* begins issuing, and this short period of confinement does not have a detrimental effect. As the adults emerge they are removed hourly from the capsules and placed in glass tubes 8 by 2 inches. The sexes are kept separate. A sponge dampened with a mixture of equal parts of honey and water is placed in each tube. The tubes are then placed in a cool, dark place until ready for use.

Several different types of cages and trays have been tried as breeding chambers with varying degrees of success. *A. melanoscelus*, like most hymenopterous parasites, is extremely heliotropic and individuals are found resting on the sides or top of the container or exhausting themselves flying about the source of light. During the past summer a breeding chamber was devised which eliminated the unsatisfactory light conditions of previous cages (Pl. V, A, B, C). This type of breeding chamber should prove of value in breeding work with other parasites.

The empty chamber is shown in Plate V, A, resting on one side. It is merely a wooden case with a glass bottom and top, with an opening left in one end, through which the tray containing the larvæ to be parasitized is admitted. The opening is just wide enough to allow the introduction of the tray and is about 2 inches deeper than the tray. Cleats on which the tray is to rest are arranged inside the chamber about 2 inches from the bottom. The tray should fit closely to the sides and ends of the chamber, but not tightly enough to bind when being introduced or removed. After the tray has been put in place the opening in the end of the cage is closed with a tightly fitting board (Pl. V, A at X).

When the chamber is to be stocked with the parasites it is placed on a flat surface which has previously been covered with black paper (Pl. V, B). A piece of black paper is laid over the top, covering all but 6 or 7 inches of the glass at the end of the chamber facing the sun (Pl. V, B at L). The parasites are liberated in the cage and fly to the uncovered part of the chamber where they gather on the glass top. The tray containing the small caterpillars is slid into place and is shown, part way in, in Plate V, B at T. The open end of the chamber is now closed and the whole thing is removed to two wooden horses, as shown in Plate V, C. A piece of black paper is now placed over the entire top.

**APANTELES MELANOSCELUS.**

A, Breeding chamber resting on its side; *x*, Board to close open end; *B*, Chamber ready to stock with parasites and gipsy-moth larvae. Tray containing gipsy-moth larvae shown at *t*, part way in; the light is admitted at *l*. *C*, chamber resting on horses, with light entering from bottom only.



With this arrangement all of the light entering the chamber comes from beneath, through the glass bottom of the chamber and through the cloth-covered bottom of the tray. Five minutes after the chamber is in this position practically all of the *Apanteles* have left the top of the chamber and are found dispersed over the bottom of the tray, where the gipsy-moth larvæ are feeding and crawling. The parasites begin ovipositing in the caterpillars immediately after they have been attracted to the bottom of the tray.

When the caterpillars have been exposed to *Apanteles melanoscelus* for a sufficient period the operations are reversed; the chamber is placed on a black-covered surface with the end of the chamber opposite the end where the tray is to be removed, facing the sun. Light is now admitted by removing the black paper over a space of 6 or 7 inches, as shown in Plate V, B at L. In a few minutes most of the parasites will congregate in the top of the chamber at the light end. The opposite end of the chamber can now be opened without danger of any of the parasites escaping. The tray is withdrawn slowly, care being taken that all of the *Apanteles* have left it. If any still remain, they will fly to the light end of the chamber when disturbed by touching them with a small camel's-hair brush.

As soon as the tray has been removed another one is introduced and the process is repeated as long as the supply of *Apanteles melanoscelus* lasts. The larvæ parasitized in this manner are fed in the trays until the parasite maggots issue. The resulting cocoons are removed each day for colonization.

A breeding chamber stocked with 300 adults of *Apanteles melanoscelus*, with the sexes equally divided, can be used about one week. Each tray should contain about 10,000 first-stage gipsy-moth larvæ.

The period of exposure of the larvæ to the parasites varies with the temperature and time of day. The parasites are most active during the middle of the day. The larvæ were enclosed in the chamber about two hours during this part of the day. Earlier in the morning and later in the afternoon the larvæ were exposed for about three hours. An average of about 1,000 parasite cocoons were removed from each tray. Undoubtedly many more than a thousand larvæ were parasitized in each tray, but there is always a certain amount of unavoidable mortality of first-stage larvæ in feeding trays. Many of the larvæ are weak and do not get to the food and many are injured when the trays are cleaned and the larvæ fed.

SUCCESS OF COLONIES AND DISTRIBUTION OF A. MELANOSCELUS.

Records of the success or establishment of colonies liberated and of the distribution of the parasite are obtained by collecting host material from the field and rearing the parasite from these larvæ at the laboratory, or by collecting the cocoons of the parasite in the field.

Often the parasite is recovered the year following colonization. *A. melanoscelus* has been recovered from all but one of the colonies liberated previous to 1918. It has been recovered from half of the colonies put out in 1918 and from both of the colonies liberated in 1919. Recoveries of the parasite were made late in the summer of 1920 in a few of the towns which were colonized during June of that year.

DISPERSION.

The inner black line on the map (Pl. IV) shows the present known distribution of the parasite in New England, it having been recovered from practically every town within this line. It is probable that in some cases *A. melanoscelus* has spread beyond the line indicated, for many of the towns just outside of the dispersion line have not been scouted.

It is rather difficult to determine the exact distance the parasite will spread in a year, for when the parasite is scarce its recovery is largely a matter of chance. The number of host larvæ which it is practical to collect in an endeavor to rear the parasite for dispersion records is infinitesimal when compared with the larvæ present in a town. Scouting for the cocoons is more satisfactory, but this is not infallible, and the fact that a town may have been scouted and no cocoons found does not prove that the parasite is not present.

The recovery records show that the greatest spread of this species has been to the north and northeast, similar to the dispersion of the gipsy and brown-tail moths. The data obtained indicate a spread of about 25 miles a year in this direction. During the summer of 1918 there were two recoveries made which because of their locations are of special interest. One of these recoveries was made at Provincetown, which is 25 miles northeast of Harwich, where the nearest colony of *A. melanoscelus* was liberated in 1915. The other recovery was made on the island of Nantucket, which is 25 miles south of the Harwich colony. In 1915 a colony of *A. melanoscelus* was liberated in Middleboro, about 33 miles southwest of Provincetown. The colonies at Harwich and Middleboro were the only ones that had been liberated in that part of the State. These recovery records can not be taken as absolute proof of a flight of 25 miles for the insect, as it is possible that cocoons of the parasite were taken to Provincetown and Nantucket on cordwood or other material. This does not seem likely, however, for the parasite was not recovered from any of the other towns in southeastern Massachusetts until 1919. The number of cocoons taken at Provincetown and Nantucket in 1918 indicated that the parasite had been present in both places for 1 year at least.

SECONDARY PARASITISM.

Cocoons of the first generation are not seriously attacked by secondary insects. Small collections of cocoons of this generation are made each year over a considerable area and rarely are they parasitized over 10 per cent; more often not more than 2 or 3 per cent are killed by secondaries.

Unfortunately it is a different story with the hibernating brood, for approximately 75 per cent are killed annually by native secondary insects and ants. This seriously handicaps the increase of *A. melanoscelus*. Among the insects which have been reared from the hibernating cocoons are at least three Ichneumonidae, and members of the Pteromalidae, Elasmidae, Eurytomidae, Entedontidae, and Eupelmidae. In this complex there are secondary, tertiary, and possibly quaternary and quinquenary insects. An investigation of the life histories and host relationships of these insects has received considerable attention at the laboratory, but has not been completed. Some of these insects have several generations during the early fall and then hibernate within the cocoons of *A. melanoscelus*.

THE VALUE OF *A. MELANOSCELUS* AS A GIPSY MOTH PARASITE.

The problem of obtaining the actual percentage of parasitism of the gipsy moth by *A. melanoscelus* or by any of the other introduced parasites, except the egg parasites, is a difficult and complicated matter involving many factors. Records at the Gipsy Moth Laboratory show that larvæ picked promiscuously from tree trunks and foliage to-day may give 30 per cent parasitism, while to-morrow the same number of larvæ, collected by the same individual, in the same manner, and in the same locality, may not even show the presence of the parasite.

For a number of years collections of gipsy-moth larvæ have been made daily through the entire larval period at Melrose and Stoneham, in an attempt to learn the true status of the parasites in that section. Each collection contained 100 larvæ all of the same stage. The collections of each stage were continued as long as that particular stage could be found, and collections of the next stage were started as soon as 100 larvæ of the next stage could be found. As there is quite an overlapping of stages, there were very often two collections on the same date at the same place. All of the collections were kept separate and the larvæ were fed in trays until all of the parasites had issued. The trays were examined each day and any parasites which issued were removed and recorded. Individual collections, containing 100 caterpillars each, gave from nothing to as high as 40 per cent parasitism of second-stage gipsy-moth larvæ for the spring

generation of the parasite. The records of parasitism secured from fourth-stage caterpillars which represent the second or summer generation of *A. melanoscelus* were about the same.

The second and fourth stages of the gipsy-moth larvæ usually showed the highest percentage of parasitism, but a considerable number of the individuals of the other stages were killed by the parasite. Occasionally collections were made which gave as high as 15 per cent parasitism, for each of the other larval stages. In large collections of larvæ where all the caterpillars in sight were collected, the parasitism obtained averaged around 10 per cent for each generation. The collections from which these figures were secured contained from 5,000 to 20,000 larvæ.

The figures obtained from the foregoing collections should not be taken as representing the value of the parasite.

There are a great many parasitized gipsy-moth larvæ which die in the field before the parasite maggot has had time to develop. The parasitized larvæ do not eat so much as nonparasitized larvæ and are inclined to crawl to out-of-the-way places and often are not seen by the collector. On the other hand, if one should search for the hidden larvæ the collection would not be representative of conditions as they truly exist.

There is each year a high percentage of mortality of the gipsy moth, which occurs whether insect parasites are present or not. This mortality varies from year to year depending upon the conditions which influence the contributing factors, but the average percentage of mortality (barring insect parasites) for any period of years is the same as for any other similar period of years, if the periods include a sufficient number of years to make the average a fair one. This average mortality is not sufficient to prevent the increase of the gipsy moth, nor is the parasitism by *A. melanoscelus* great enough to prevent the increase of this pest. Although the exact percentage of parasitism of the gipsy moth by this parasite can not be stated, it is evident that it has a very important place as a part of the sequence of parasites which in conjunction with the other natural agencies retards the increase of this injurious insect.

ABUNDANCE OF *A. MELANOSCELUS* IN NEW ENGLAND.

Apanteles melanoscelus, like some of the other introduced parasites of the gipsy moth, is found abundantly in rather small areas. Each year since the parasite has been established these areas of abundance have been found more often and over considerably more territory. Until the summer of 1916 the parasite was not found in any appreciable numbers excepting at local points in and around Melrose Highlands. During the summer of that year a location at Beverly, Mass., was found where *A. melanoscelus* was very common. During the

same summer some interesting data were obtained from a medium-sized oak tree near the Gipsy Moth Laboratory at Melrose Highlands. This tree had many gipsy-moth egg clusters on it which had not been creosoted during the winter, so that on this particular tree there was a much heavier infestation of gipsy-moth larvæ than on any of the other trees in the vicinity. As the summer progressed, cocoons of *A. melanoscelus* began to appear in surprisingly large numbers. When most of the first-generation maggots had issued and spun their cocoons, the underside of nearly every crotch on the tree was covered with *Apanteles* cocoons (Pl. II, C).

There were 5,140 first-generation cocoons collected from this tree. A few cocoons could not be reached and some had blown away before the collection was made. Later in the season 511 second-generation cocoons were taken from the tree, making a total of 5,651 cocoons of *A. melanoscelus* removed from this tree. Although heavily infested the foliage on the tree was not damaged much by the feeding of the gipsy moth larvæ and very few gipsy-moth pupæ were found on the tree. These data are not given as a sample of the condition of the trees in Melrose Highlands in 1916, but the figures are interesting and show what happens under some conditions. Occasionally large oak trees have been seen in other towns on which it was estimated there were from 6,000 to 10,000 cocoons.

In 1918 this parasite was found in large numbers over an area of several acres of woodland in Cohasset. In 1919 and 1920 it was found abundantly in small areas in Hampton, N. H., and in the following towns in Massachusetts: Beverly, Quincy, Weymouth, Cohasset, Scituate, Marshfield, and West Boylston.

CONCLUSION.

Apanteles melanoscelus has been present in New England since 1911 and is now firmly established. It is spreading rapidly from the colonies which have been liberated and is increasing in spite of its being heavily parasitized by secondaries.

The fact that *A. melanoscelus* is able to complete its life cycle on several native insects adds considerably to its value as an introduced parasite and makes its permanent establishment more certain than if the gipsy moth were its only host.

This parasite has two generations each year on the gipsy moth and is very abundant in many small areas. It gives promise of becoming one of the most valuable of the imported parasites.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY



UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1029

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.

PROFESSIONAL PAPER

March 28, 1922

SEED TREATMENT AND RAINFALL IN RELATION TO THE CONTROL OF CABBAGE BLACK-LEG.

By J. C. WALKER, *Assistant Professor of Plant Pathology, University of Wisconsin, and Pathologist, Office of Cotton, Truck, and Forage Crop Disease Investigations.*¹

CONTENTS.

	Page.		Page.
Introduction	1	Field trials with treated seeds—Con.	
Effect of fungicidal treatment in the laboratory upon seed and the seed- borne fungus	3	Relation of rainfall to the de- velopment of the disease.....	14
Heat and desiccation.....	5	Importance of spread in the seed bed as compared with	
Formaldehyde solution.....	7	dissemination in the field....	17
Hot water.....	9	Seed-bed trials at Madison, Wis., in 1919.....	18
Mercuric-chlorid solution.....	10	Results with treated seeds in commercial fields.....	20
Summary of laboratory seed- treatment experiments.....	12	Importance of disease-free seeds....	23
Field trials with treated seeds.....	13	Summary.....	25
Development of the disease in the seed bed.....	13	Literature cited.....	27

INTRODUCTION.

The black-leg of cabbage, first noted as occurring in America by Manns (7),² has become one of the most serious and widespread maladies of this crop. Henderson (3), who, on the basis of his earlier studies in Wisconsin, has given the most complete treatise on the disease, demonstrated that cabbage seeds which had been invaded by the causal fungus, *Phoma lingam* (Tode) Desm., were a common

¹ The major portion of the work reported upon herewith was carried on at the laboratory of plant pathology of the University of Wisconsin as a cooperative project between the university and the United States Department of Agriculture. Along with this, the writer has had opportunity for field studies in some of the chief cabbage-growing sections in the Eastern, Western, and Southern States. The writer wishes to express his appreciation to Prof. L. R. Jones for the helpful advice and criticisms received during the course of the investigation and to Dr. W. B. Tisdale and Miss Ruth Tillotson for assistance in part of the field observations and laboratory experiments.

² The serial numbers (italic) in parentheses refer to "Literature cited" at the end of this bulletin.

source of primary inoculum the following year. As he pointed out, it has been the experience of many growers that the appearance of this disease in epiphytotic form in a given locality is usually associated with a certain lot of cabbage seed. Observations by the writer have strengthened the belief that infected seed is the chief cause of heavy losses from black-leg.

Henderson (3) found that naked pycnospores of *Phoma lingam* were killed within two or three minutes by 1:200 formaldehyde or 1:1,000 mercuric-chlorid solutions. Spores within pycnidia embedded in soft cortical tissues of the host were killed after 21 minutes by the formaldehyde solution, while with the other fungicide a few spores were still viable after this length of treatment. Henderson's study was limited by the small number of infected seeds available. It was found, however, that after treatment in 1:200 formaldehyde solution for 21 minutes or in 1:1,000 mercuric-chlorid solution for 10 minutes, infected seeds still yielded pure cultures of *Phoma lingam*.

In 1917 a crop of the yellows-resistant Wisconsin Hollander seed was grown at Racine, Wis. A scattering of *Phoma lingam* developed on the seed plants, and a very small percentage of the pods became infected. All of this seed (approximately 25 pounds) was treated with a 1:256 solution of formaldehyde, and most of it was planted in the same locality the following season. Black-leg developed in epiphytotic form in most of the seed beds, resulting in heavy crop losses where such plants were set in the field. A typical field from this lot of seed as it appeared at the end of the season is shown in Plate I, A. The uniformity with which the disease developed in beds from the lot of seed in question and the fact that many of these beds were on soil which had not grown cabbage for many years left no doubt that the fungus carried over in the seed was the source of infection. Moreover, it was evident that despite seed treatment the parasite had spread from comparatively few centers to a large percentage of the plants during their growth in the seed bed.

This situation raised the important question as to how much reliance is to be placed upon seed treatment as a means of control for black-leg. Experiments and observations reported later in this paper show that a very small percentage of infected seeds may under certain environmental conditions cause almost a total loss of the crop. Moreover, the detection of such infected seeds is very difficult, even by an expert. Since a very large portion of the cabbage seed used in this country is grown in a few restricted areas in America and abroad, the average grower uses seed concerning the history of which he knows very little, and this fact makes it the more necessary either that seed treatment be entirely effective or that the production of *Phoma*-free seed be insured.

It was upon the basis of these facts that the present investigation was begun. It was necessary, first of all, to determine more definitely the limitations of seed treatment with the common disinfectants, both upon commercial cabbage seed and upon the black-leg fungus within infected seeds. Following this, the relation of certain environmental factors to the development and spread of the disease, especially in the seed bed, and their influence upon the ultimate success of seed treatment were studied. This paper is a progress report upon the work along these lines.

EFFECT OF FUNGICIDAL TREATMENT IN THE LABORATORY UPON SEED AND THE SEED-BORNE FUNGUS.

Because of its practical bearing upon the efficacy of seed treatment, an extensive study was made of the resistance of the fungus within infected seeds to heat, desiccation, and chemical fungicides, and, as a necessary corollary, experiments on the effect of the same treatments upon normal cabbage seeds were performed. Early experiments showed that it would be impossible completely to disinfect seed without producing some detrimental effect upon its vitality. From the standpoint of practical cabbage culture, however, seed treatment can be carried somewhat beyond the point of first injury with profit if sufficient benefit is to be derived from fungicidal action. Moreover, as will be pointed out later, where it is desirable to rid small quantities of "mother seed" of the black-leg fungus before introducing the seed into a new locality, quite severe treatment may be desirable with the aim of complete eradication of the parasitic organism. For these reasons, in the laboratory experiments treatment with disinfectants was usually prolonged to the point where complete eradication was attained, and the effect upon commercial seeds up to that point was determined.

Four types of treatment were used: (1) Mercuric chlorid, (2) formaldehyde, (3) hot water, and (4) desiccation at moderate and high temperatures. For the study of the effect of treatment upon the fungus, seeds directly beneath or very close to pod lesions were collected shortly before maturity. Two such lots were used, one (No. 4-18) secured in a field of the Wisconsin Hollander variety at Racine, Wis., in July and August, 1918, and the second (No. 1-19) collected by Mr. E. E. Clayton from a field (variety not determined) at Mattituck, Long Island, N. Y., in July, 1919. The earlier and more extensive experiments were performed with the former lot, and the stronger treatments were repeated or performed for the first time with the latter.

The seeds were exposed to the various treatments and placed on potato-agar plates. They were kept at room temperature for two to four weeks, within which time the fungus, if viable, was identified by its growth on the medium.

Histological studies to trace the course of the mycelium within and beneath the seed coat have not been made. It became evident, however, as a result of cultural studies, that the effect on diseased seeds may vary from little or no change in normal color and little shriveling to very marked shrinkage and entire loss of vitality, dependent upon the extent of invasion by the fungus. That the infection may be confined to the seed coat is shown by one instance where a seed which had been treated with 1:1,000 mercuric chlorid to kill organisms on the surface was placed on a potato-agar plate. Normal germination occurred and the hypocotyl as it developed became attached to the agar about half an inch away from the seed coat. As growth proceeded the young seedling was drawn entirely away from contact with the testa and was later removed to a tube of agar, where it remained sterile. Subsequently, however, a pure culture of *Phoma lingam* developed from the seed coat, proving that the fungus was present in this portion of the seed without having invaded the cotyledons.

In the study of the effect of fungicides upon germination and subsequent development of seedlings from normal cabbage seed, most of the work was done with two lots (Nos. 2-18 and 3-18) of the Wisconsin Hollander variety grown at Racine, Wis., in 1918. In general, one lot (No. 2-18) showed more injury from disinfectants than the other, in spite of the fact that a high percentage of the untreated seeds germinated and produced vigorous seedlings. This may have been due to improper curing, since the seed plants after being harvested were piled indoors before the seed was thrashed and the circulation of air provided was insufficient for rapid and thorough curing. A portion of lot No. 2-18 was stored in a cloth sack in the laboratory, and certain of the treatments were repeated in the second year (winter of 1919-20). After the general limits of injury with these two lots of seed had been determined, the effect of stronger treatments was usually extended to several other lots of various ages and from different sources.

In a few of the early experiments germination tests were made in Petri dishes lined with moistened filter paper. It was found that numerous treated seeds often gave evidence of germination by throwing off the testa and starting growth of the hypocotyl, but development ceased at this point. When parallel tests were made in soil in the greenhouse, most of such seedlings never appeared above ground. Consequently, in order to secure a more definite index of the capacity of various lots of seed for producing vigorous seedlings after treatment, the Petri dish method was discarded. All results reported on the effect of fungicides upon commercial seeds are from tests made in silt-loam soil in the greenhouse. The final estimate of the amount of injury was supplemented in the case of the stronger treatments

by seed-bed trials on silt-loam garden soil at Madison and on sandy soil at Racine, Wis.

In rinsing seed after treatment with mercuric-chlorid or formaldehyde solution one thorough washing in clean tap water was made. As pointed out by Robinson (9), who showed that a slight amount of the former fungicide was present in the fourth wash water after treatment of pea, bean, vetch, and barley seeds, it is probable that this one rinsing was insufficient completely to remove the fungicides.

HEAT AND DESICCATION.

Atanasoff and Johnson (1) have given a summary of previous work on the relation of high temperatures to the viability of various seeds. They studied further the effect of dry heat upon barley, wheat, rye, and oat seeds and upon a number of seed-borne organisms. It was concluded that the bacteria causing blights of barley (*Bacterium translucens*) and of oats (*Pseudomonas avenae*) could be successfully eradicated from infected seeds by dry heat, while several fungus parasites of cereals were either eliminated or markedly reduced by the same treatment. Harrington and Crocker (2) found that the percentage of germination of wheat, barley, Sudan grass, Kentucky bluegrass, and Johnson grass was not materially changed when the moisture content was reduced to less than 1 per cent by drying over calcium oxid or sulphuric acid at room temperature. Waggoner (10), by drying radish seeds first at 60° C. and then at 100° C., reduced the moisture content from 4 per cent at normal air-dry condition to 0.4 per cent without reduction of germination.

In the experiments reported here several lots of cabbage seed, varying in age from a few months to 7 years, were reduced to constant weight at 100° C. In these lots the moisture content of the air-dry seeds, untreated, remained around 6 or 7 per cent of the dry weight. The results given in Table I show that at 85° C. the moisture content dropped rapidly during the first 6 hours and then became nearly constant after 48 hours. Seed treated with mercuric-chlorid solution became adjusted to its original air-dry moisture content within a few weeks.

All of the drying experiments reported were carried out in a Freas constant-temperature electric oven. Seeds were placed for this purpose in thin layers in small paper containers, so as to avoid direct contact with substances of high specific heat.

Desiccation at high temperatures (85° to 95° C.) caused a gradual reduction in viability, which was accompanied by retardation in germination and growth. The plants might outgrow the effects of mild treatments, but severe injury was usually permanent. In the early experiments, in which No. 3-18 seed was used, only slight in-

jury to the seed was caused at 96 hours; therefore this method gave some promise as a practical means of control. When it was extended to other seed lots, however, the deleterious effects of the treatment became evident at a much shorter exposure. This was most noticeable in the case of No. 2-18 seed when treated in the second year.

TABLE I.—*Effect of desiccation and heat upon commercial cabbage seeds and upon the black-leg fungus within infected seeds.*

Treatment and length of exposure.	Effect upon infected seeds.				Effect upon commercial seeds.															
	Seed lot.	Number of seeds used.	Seeds with viable fungus after treatment (per cent).	Seeds with viable fungus and germinating (per cent).	One-year-old seed.												Two-year-old seed.			
					Lot 3-18. ^a				Lot 4-19. ^b				Lot 10-18. ^c		Lot 2-18. ^a		Lot 2-18. ^a			
					Dry-weight moisture content (per cent).	Germination (per cent).	Seedling injury. ^d		Dry-weight moisture content (per cent).	Germination (per cent).	Seedling injury. ^d		Germination (per cent).	Seedling injury. ^d	Germination (per cent).	Seedling injury. ^d	Dry-weight moisture content (per cent).	Germination (per cent).	Seedling injury. ^d	
Untreated:																				
No exposure.....	4-18	130	75.3	22.3																
Exposed at constant temperature:	1-19	24	66.6	0	6.38	97	○		6.9	92	○		93	○		92	○	7.11	77	○
At 85° C.—																				
1 hour.....									3.17	77	○							2.69	37	+
2 hours.....									2.97	64	○							2.31	38	+
4 hours.....									1.69	79	○							2.25	37	+
6 hours.....	4-18	22	40.9	0	1.27	95	○		1.51	62	+	○				94	○	2.12	33	+
12 hours.....	4-18	49	32.6	6.1	1.27	97	○		1.42	67	+	+	87	○		85	○	1.85	29	+
24 hours.....	4-18	45	17.7	8.8	1.02	95	○		1.22	54	+	+	88	○		90	○	1.85	20	+
30 hours.....	4-18	49	20.4	0		85	95									84	+			
36 hours.....	4-18	46	4.3	0		85	96		1.29	63	+	+				84	+	1.92	32	+
48 hours.....	4-18	25	36.0	16.0		72	95		1.15	42	+	+	71	+		74	+	1.63	22	+
72 hours.....	4-18	44	9.0	2.2		93	96		.73	31	+	+	58	+		55	+	1.32	13	+
96 hours.....	4-18	49	0	0		.78	87		1.22	25	+	+	17	+		53	+	1.63	14	+
120 hours.....	4-18	49	0	0					1.10	17	+							1.60	12	+
At 90° C.—																				
12 hours.....	4-18	24	25.0	0		93	○						70	○		78	+			
24 hours.....	4-18	25	4.0	0		63	○						77	○		29	+			
36 hours.....	4-18	24	4.1	0		57	+						70	○		30	+			
48 hours.....	4-18	48	4.1	0		10	+						16	+		0				
60 hours.....	4-18	24	0	0																
72 hours.....	4-18	47	0	0		3	+						38	+		3	+			
At 95° C.—																				
1 hour.....					2.06	86	○		46	+								2.53	10	++
2 hours.....					1.40	80	○		58	+								2.09	1	++
4 hours.....					1.02	85	○		55	+								1.85	5	++
6 hours.....					.68	88	○		56	+								1.74	2	++
12 hours.....	4-18	35	2.8	0	.72	87	○		53	+		34	+		66	+	1.85	1	++	
18 hours.....	4-18	23	0	0											33	+				
24 hours.....	4-18	24	0	0	.48	77	○		21	+		8	+		9	+	1.76	2	++	
36 hours.....	4-18	20	0	0	.36	21	+		35	+		2	+		0		1.75	1	++	
48 hours.....					.25	0			15	+							1.63	0	++	
72 hours.....					.31	0			0	+							1.74	0	++	
96 hours.....					.27	0														
Dried at 37° to 50° C. 5 days,																				
at 73° 3 days, then at																				
100° C.:																				
0 hour.....					1.31	90	○													
12 hours.....						22	+													
24 hours.....						0														
36 hours.....						0														

^a Wisconsin Hollander variety grown at Racine, Wis., in 1918.

^b All Seasons variety grown at La Conner, Wash., in 1919.

^c Wisconsin All Seasons variety grown at Racine, Wis., in 1918.

^d Symbols used: ○ = No injury; ⊖ = slight; ± = medium; + = severe; ++ = very severe.

It will not be necessary to consider in detail the data obtained when the seeds were exposed at 90° and 95° C., as listed in Table I. Lot No. 3-18 again proved to be the most resistant, while the remaining lots, as a rule, received marked injury at these temperatures. Parallel treatments of highly infected seeds showed that the fungus had been killed within 18 hours at 95° C. and within 96 hours at 85° C. Both of these treatments might, therefore, be of practical use with lot No. 3-18, but would be very injurious to the other lots.

A quantity of No. 3-18 seed was dried first at 37° to 50° C. for five days, then at 73° C. for three days, by which means the moisture content was reduced to 1.31 per cent. The seed was then placed in an incubator running at 100° C. The results (Table I) showed that in spite of the reduced water content the ability to resist this high temperature was not increased. Agar-plate tests with badly infected seed similarly treated were not made. However, a sample dried at 40° to 50° C. for 19 days and then at 85° C. for one day, the moisture content being reduced to 1.44 per cent of the dry weight, yielded almost as much disease as untreated seed in seed-bed trials. This fact indicates that prolonged drying at moderate temperatures does not materially affect the fungus.

It is evident from the foregoing data that cabbage seed is not uniformly resistant to desiccation at high temperatures. Moreover, the fungus within or beneath the testa is so resistant to this treatment that complete eradication of it from infected seed by baking is impossible without considerable injury to the seed. These facts, together with the difficulty of applying this treatment on a large scale, give doubtful value to this method for commercial use with cabbage seed.

FORMALDEHYDE SOLUTION.

In the trials with formaldehyde solution use was made of formaldehyde, standard strength of approximately 40 per cent, diluted with distilled water. Aside from one treatment with a 1:256 solution for 37 minutes, which was approximately the same as the formula used on a commercial scale in 1918, the stronger concentration (1:128) was used throughout the experiments with formaldehyde. Unless otherwise noted the solutions were used at room temperature, approximately 20° C. Certain of the lots were rinsed in clean water; others were not rinsed. All were spread out in thin layers after treatment and allowed to dry under laboratory conditions. As will be seen from the results given in Table II, the latter treatment always produced greater injury than resulted in the case of corresponding rinsed lots.

The deleterious effect of formaldehyde upon cabbage seed becomes evident both as reduction in percentage of seed germination and as injury to the seedlings. The data in Table II show a progressive decline in the percentage of germination of commercial seeds with the

increase in length of formaldehyde treatment. Injury to the seedlings is evident first from delayed germination and later from various degrees of retardation of growth. A slight check at the outset may be overcome within a few days, but increase in the severity of treatment results in permanent stunting. Accompanying the latter there is usually definite injury to the cotyledons, which remain dwarfed and become distorted in shape. Oftentimes with milder treatments this injury is confined to that cotyledon adjacent to the seed coat, while the other develops normally.

TABLE II.—*Effect of formaldehyde solution upon the black-leg fungus within infected cabbage seeds and upon commercial seeds.*

Strength and temperature of solution.	Length of time in the solution (minutes).	Subsequent treatment.	Effect upon infected seeds.				Effect upon commercial seeds.		
			Seed lot.	Number of seeds used.	Seeds with viable fungus after treatment (per cent).	Seeds with viable fungus and germinating (per cent).	Germination (per cent).		Seedling injury. ^b
							Seed lot 2-18. ^a	Seed lot 3-18. ^a	
Untreated.....	—	—	4-18	130	75.3	22.3	93	97	○
Strength 1 to 256.....	—	—	1-19	24	66.6	0	—	—	—
At room temperature.....	30	Rinsed.....	1-19	10	50.0	10.0	—	—	—
Do.....	37	do.....	4-18	24	—	—	—	—	—
Strength 1 to 128:	—	—	—	—	33.3	0	92	98	○
At room temperature.....	15	do.....	4-18	25	16.0	0	90	—	○
Do.....	30	do.....	4-18	25	16.0	8.0	85	96	⊖
Do.....	30	do.....	1-19	15	60.0	13.3	—	—	—
Do.....	30	Unrinsed.....	1-19	23	13.0	0	66	80	+
Do.....	45	Rinsed.....	4-18	25	24.0	4.0	79	85	+
Do.....	60	do.....	4-18	25	16.0	4.0	78	88	+
Do.....	60	Unrinsed.....	4-18	25	0	0	57	69	++
Do.....	120	Rinsed.....	1-19	24	8.3	0	48	—	++
Do.....	120	Unrinsed.....	4-18	25	0	0	46	—	++
At 55°C.....	1	do.....	—	—	—	—	45	—	++
Do.....	2	do.....	—	—	—	—	46	—	++
Do.....	5	do.....	—	—	—	—	28	—	++
At 60°C.....	1	do.....	—	—	—	—	32	—	++
Do.....	2	do.....	—	—	—	—	22	—	++
Do.....	5	do.....	—	—	—	—	20	—	++

^a Wisconsin Hollander variety grown at Racine, Wis., in 1918.

^b Symbols used: ○=No injury; ⊖=slight; +=medium; ++=severe; +++=very severe.

Table II shows that severe injury with 1:128 formaldehyde solution resulted with one hour of treatment when the seed was subsequently rinsed and with 30 minutes when the seed was dried without rinsing. It is also shown that, although materially reduced, the fungus had not been completely eradicated from infected seeds by either of these treatments. Complete disinfection was not attained with rinsed seed even after two hours of treatment and only after one hour with unrinsed seed. It is worthy of note that the infected seeds were killed somewhat earlier than the invading fungus, and this in practice might reduce somewhat the number of primary infections. It will be shown later, however, that infected seeds although incapable of germination

may serve as sources of subterranean infection of near-by seedlings. Treatments with solutions heated to 55° and 60° C. for the very short periods of 1 to 5 minutes were so injurious that their effect upon infected seeds was not given further consideration. It was thus very evident that complete disinfection of infected seeds with a formaldehyde solution is impossible without material injury to the subsequent development of the plants. Moreover, the fact that protracted treatment with this fungicide results in very serious injury to the host plant precludes its use even in those special cases where complete eradication of the parasite is so much desired that moderate seedling injury would be tolerated.

HOT WATER.

The use of hot-water treatment for the control of cabbage black-leg was first suggested by Norton (8). He treated cabbage seed for 5 minutes at 60°, 10 minutes at 56°, 15 minutes at 56°, and 20 minutes at 54° C. without injuring it, while spores of the fungus were killed at somewhat lower temperatures. The effect of these treatments upon the fungus within infected seeds was not determined, however.

TABLE III.—*Effect of hot-water treatment upon the black-leg fungus within infected cabbage seeds and upon commercial seeds.*

Temperature.	Length of exposure (minutes).	Effect upon infected seeds.				Effect upon commercial seeds.					
		Seed lot.	Number of seeds used.	Seeds with viable fungus after treatment (per cent).	Seeds with viable fungus and germinating (per cent).	One-year-old seed.				Two-year-old seed.	
						Lot 2-18. ^a		Lot 4-19. ^b		Lot 2-18. ^a	
						Germination (per cent).	Seedling injury. ^c	Germination (per cent).	Seedling injury. ^c	Germination (per cent).	Seedling injury. ^c
Untreated.....		4-18	130	75.3	22.3	93	○	97	○	67	○
Do.....		1-19	24	66.6	0						
At 50° C.....	30	1-19	15	0	0	86	⊖	91	⊖	66	⊖
Do.....	60	1-19	20	0	0	85	⊖	82	⊖	46	+
At 55° C.....	5	1-19	24	29.1	0	81	⊖	86	⊖	51	+
Do.....	10	1-19	35	14.2	0	80	⊖	86	⊖	48	+
Do.....	15	4-18	17	0	0	67	+	82	⊖	33	+
Do.....	15	1-19	35	2.8	0	67	+				
At 56 to 57° C.....	20	4-18	23	0	0						
At 55° C.....	30	1-19	24	0	0	52	+	39	+	18	+
At 60° C.....	5					59	+				

^a Wisconsin Hollander variety grown at Racine, Wis., in 1918.

^b All Seasons variety grown at La Conner, Wash., in 1919.

^c Symbols used: ○=No injury; ⊖=slight; +=medium; ++=severe.

The effect of hot water held at 50°, 55°, and 60° C. both upon commercial and infected seeds has been determined by the writer, and the results of the tests are given in Table III. Treatment for 30 minutes at 55° C. completely eradicated the fungus, but considerable

injury resulted to commercial seed held at this temperature for as short a time as 5 minutes. At 50° C. the fungus was killed in 30 minutes with the small number of seeds used, but here, again, some detrimental effect upon commercial seed occurred; in fact, seed injury was evident in somewhat milder treatments than those reported by Norton (8). This is probably due to differences in the susceptibility of individual seed lots. Soaking the seed in water before treatment did not appear to be of any distinct advantage. At present, hot-water treatment does not appear to be sufficiently superior to the mercuric-chlorid treatment described later to warrant its recommendation for general use. Further comparative trials, however, should be made.

MERCURIC-CHLORID SOLUTION.

Solutions of mercuric chlorid were made by dissolving the chemically pure salt in distilled water. The treatments were all conducted at room temperature, about 20° C. Four methods were used: (1) Soaking the cabbage seed in the disinfectant without previous treatment and rinsing once in clean water after removal; (2) soaking in the disinfectant without previous treatment and allowing the seed to dry without subsequent rinsing; (3) soaking in water for one to four hours before placing in the disinfectant and rinsing once in clean water after treatment; (4) dipping the seed first in alcohol for two minutes, then transferring to the disinfectant for the desired time, and finally rinsing in clean water. Mercuric chlorid caused a gradual reduction in the percentage of germination of seeds proportionate to the length of soaking and the concentration of the solution. Injury to the germinating seedlings was characterized by temporary or permanent stunting of growth and varied amounts of necrotic tissue extending back from the margins of the cotyledons. The results of experiments with mercuric-chlorid solutions are presented in Table IV.

With the first method (soaking in the disinfectant and rinsing in water) little injury resulted from a 30-minute treatment with the 1:500 solution, and practically none from less severe treatments. In the case of one lot of imported cabbage seed of rather low vitality (not cited in Table IV), considerable injury resulted from the 30-minute 1:500 treatment, indicating that treatments as severe as this should be used with caution. In the case of most lots of cabbage seed, however, the soaking may be prolonged to one or two hours with only slight injury, and at three hours only medium retardation may be expected. These stronger treatments completely eradicated the fungus in the case of the No. 4-18 seed. The fungus in the No. 1-19 lot appeared to be much more resistant to this chemical.

TABLE IV.—*Effect of mercuric-chlorid solution upon the black-leg fungus within infected cabbage seeds and upon commercial seeds.*

Method of treatment and strength of the solution.	Length of exposure (minutes).	Effect upon infected seeds.				Effect upon commercial seeds.									
		Seed lot.	Number of seeds used.	Seeds with viable fungus after treatment (per cent).	Seeds with viable fungus and germinating (per cent).	One-year-old seed.									
						Lot 3-18. ^b					Lot 4-19. ^c				
						Germination (per cent).	Seedling injury. ^e	Germination (per cent).	Seedling injury. ^e	Germination (per cent).	Seedling injury. ^e	Germination (per cent).	Seedling injury. ^e	Germination (per cent).	Seedling injury. ^e
Untreated.....	4-18	130	75.3	22.3	95-100	○	96	○	92	○	92	○	80	○	○
Do.....	1-19	24	66.6	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Method 1:															
Strength 1 to 1,000.....	10 4-18	25	56.0	4.0	99	○	.....	.....	.....	.....	.....	.....	.....	.....	.....
	20 4-18	25	20.0	0	97	○	.....	.....	.....	.....	.....	.....	.....	.....	.....
	30 4-18	24	16.6	4.1	99	○	.....	.....	.....	.....	.....	92	○	.....	.....
	40 4-18	25	12.0	0	99	○	.....	.....	.....	.....	.....	.....	.....	.....	.....
	60 4-18	25	12.0	0	99	○	.....	.....	.....	.....	.....	.....	.....	.....	.....
	10 4-18	25	20.0	12.0	99	○	.....	.....	.....	.....	.....	.....	.....	.....	.....
	20 4-18	25	36.0	8.0	98	○	.....	.....	.....	.....	.....	.....	.....	.....	.....
	<i>f</i> 20 1-19	10	20.0	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	30 4-18	25	12.0	4.0	98	○	93	○	94	○	88	○	85	○	○
	<i>f</i> 30 1-19	10	50.0	20.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Strength 1 to 500.....	40 4-18	25	12.0	4.0	98	○	98	○	90	○	81	○	82	○	○
	60 4-18	39	12.8	2.5	93	○	.....	.....	.....	.....	.....	.....	.....	.....	.....
	60 1-19	22	63.6	1.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	120 4-18	24	0	0	.....	.....	85	○	77	○	63	○	71	○	○
	120 1-19	25	4.0	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	180 4-18	25	0	0	.....	.....	84	○	70	○	57	+	63	+	+
	180 1-19	28	28.5	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Method 2:															
Strength 1 to 500.....	30 4-18	13	15.3	.....	87	○	.....	.....	.....	.....	.....	72	○	.....	.....
	60 4-18	25	0	0	64	○	.....	.....	.....	.....	.....	74	○	5	○
	60 1-19	25	8.0	8.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
	120 .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	53	○	.....	.....
Method 3:															
Strength 1 to 500.....	10 .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	81	○
	20 .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	78	○
	30 1-19	24	20.8	8.3	.....	.....	.....	.....	.....	.....	.....	.....	.....	74	○
	60 .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	42	+
	120 .....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	13	++
Method 4:															
Strength 1 to 500.....	10 .....	.....	.....	.....	.....	.....	.....	94	○	.....	.....	.....	.....	.....	.....
	20 .....	.....	.....	.....	.....	.....	.....	95	○	.....	.....	.....	.....	.....	.....
	30 .....	.....	.....	.....	.....	.....	.....	95	○	.....	.....	.....	.....	.....	.....
	60 1-19	<i>g</i> 50	62.0	2.0	.....	.....	.....	83	○	.....	.....	.....	.....	.....	.....
	120 .....	.....	.....	.....	.....	.....	.....	51	○	.....	.....	.....	.....	.....	.....

^a Method 1=not soaked previous to treatment, rinsed after treatment; method 2=not soaked previous to treatment, not rinsed after treatment; method 3=soaked in water previous to treatment, rinsed after treatment; method 4=dipped in 70 per cent alcohol previous to treatment, rinsed after treatment.

^b Wisconsin Hollander variety grown at Racine Wis., in 1918.

^c All Seasons variety grown at La Conner, Wash., 1919.

^d Jersey Wakefield variety grown at La Conner, Wash., 1919.

^e Symbols used: ○=No injury; ⊖=slight; ⊕=medium; ⊕+=severe; ⊕⊕+=very severe.

^f Disinfected by seed grower.

^g Dipped in 95 per cent instead of 70 per cent alcohol.

With the second method of treatment (soaking in the disinfectant without rinsing in water), seedling injury occurred after a shorter period, evidently as a result of the prolonged action of the disinfectant. No advantage of this over the first method was found, however, since the action upon the fungus was no more rapid than upon the host.

A limiting factor in the use of mercuric-chlorid solution is the fact that complete contact with the seed coats is usually prevented by the presence of small air bubbles. To overcome this difficulty Hutchinson and Miller (4) conducted their seed treatments in partial vacuum, but with only limited success. Since two trials with infected seed by this treatment in 1:500 mercuric chlorid gave no better results than parallel experiments at atmospheric pressure, the method was abandoned (see Table IV).

In order to overcome this difficulty in another way the seed was soaked in water previous to treatment (method 3). The action of the fungicide on the seeds was more rapid than with the unsoaked seed, marked injury resulting from treatments of more than 30 minutes' duration. At this point, however, the disinfection of diseased seed was no more complete than with similar exposures of unsoaked seed.

In the fourth method of treatment, where seeds were rinsed in alcohol before exposure to the mercuric-chlorid solution, the action of the disinfectant was hastened somewhat, injury to the seed being pronounced after a treatment of one hour (see lot No. 4-19, Table IV). The method appears to be no more effective than the first, however, in eradicating the fungus from infected seeds.

The results with mercuric chlorid may be summarized as follows: With most lots of seed used a soaking of one hour in a 1:500 solution followed by rinsing in water caused very slight seed injury. One lot, however, was injured considerably by this treatment. Treatment was necessary for two hours for complete eradication of the fungus in the case of one lot of infected seed, and in another lot treatment for three hours was insufficient to attain this result. Other methods used with mercuric-chlorid solution—(1) soaking in the disinfectant without rinsing after treatment, (2) presoaking in water before treatment, (3) dipping in alcohol before treatment, and (4) treatment in partial vacuum—did not appear to be superior to the first. For general use soaking for 30 minutes in a 1:1,000 solution, followed by rinsing in water, is advisable. Most lots of seed will stand a 1:500 solution for a somewhat longer time, but preliminary trials should be made before this stronger treatment is applied.

SUMMARY OF LABORATORY SEED-TREATMENT EXPERIMENTS.

The data presented justify the conclusion that no known method of cabbage-seed disinfection can be relied upon for the complete eradication of the black-leg fungus, *Phoma lingam*, without severe injury to the seed. It is also evident that different lots of seed vary widely in their relative susceptibility to injury from seed treatment. This forces one to be the more conservative in recommendations for general practice. The results of experiments lead the writer to

doubt whether dry heat can be used successfully on a commercial basis because of the wide range of susceptibility to injury in different lots of seed and because of the difficulty of application. The experiments conducted with hot water have not shown it to be superior to the chemical fungicides; so in view of the awkwardness of its application it is not at present considered suitable for general use. Further comparative trials, however, should be made. With the chemical fungicides, treatment stronger than a 1:256 or 1:240 solution of formaldehyde and a 1:1,000 solution of mercuric chlorid for 30 minutes, followed by rinsing, is unsafe for general use. Of these two treatments the mercuric chlorid seems to be slightly superior in eradicating the fungus. It is true, however, that many lots of seed will stand much more severe treatment, especially with mercuric chlorid, but in the event of such treatment preliminary tests should always be made.

FIELD TRIALS WITH TREATED SEEDS.

The results from seed treatment showed that complete elimination of seed infection is impracticable. It was evident, however, that the more effective treatments, such as 1:1,000 and 1:500 mercuric-chlorid solution and 1:256 formaldehyde solution for 30 minutes destroyed or inhibited so much of the *Phoma* as greatly to reduce the percentage of seedling infection. The question arose, therefore, as to whether any of the foregoing treatments would control the disease for practical purposes. In general, infected seeds were less resistant than the fungus within them. It was reasonable to expect, then, that treatment of commercial seed bearing an ordinary amount of infection would reduce the number of germinable diseased seeds to a very low percentage.

Field observations have shown that the rapidity with which the disease develops and spreads from primary centers in the seed bed varies greatly from year to year. Comparison of climatic conditions with the occurrence of the disease in different localities and in the same locality in successive years has indicated that the amount of rainfall and the atmospheric humidity are the chief factors in causing these variations. McAlpine (6) has pointed out that the disease in Australia thrives best in wet weather followed by heat or when the plants are forced by excessive watering. This view is further strengthened by the fact that a good supply of moisture is necessary to bring about the discharge of pycnosporos of *Phoma lingam* and that they are at the same time best adapted to dissemination by spattering rain or surface drainage water.

DEVELOPMENT OF THE DISEASE IN THE SEED BED.

As described by Henderson (3), primary infection of germinating seedlings takes place at some point on the cotyledon or at the base

of the hypocotyl. In the first case invasion by the fungus takes place before or during germination. In rare cases the testa remains attached to one of the cotyledons, and delayed infection may thus occur. The disease appears as shriveling of the infected tissue of the cotyledon without much loss of color, beginning usually at the margin and progressing toward the petiole. Pycnidia later appear in the shrunken tissue, their development being materially hastened in humid environments. Infection at the base of the hypocotyl usually takes place after germination, inoculum coming from the fungus within the seed coat, which ordinarily remains below ground, closely adjacent to the crown. In the same way nongerminable infected seeds may be the source of inoculum for near-by healthy seedlings. This has been shown to take place by planting such seeds alternately in the furrow with healthy viable ones. In the case of hypocotyl infection, the disease appears above ground as a gradual shrinkage of the succulent tissue, progressing upward and ultimately causing a collapse of the plant. As in the case of cotyledon infection, pycnidia later appear in the shrunken tissue, their development likewise being enhanced by moist environment. Under greenhouse conditions where a temperature of 70° to 75° F. and a relative humidity of about 60 to 70 per cent were maintained, the first signs of disease usually appeared in 8 to 10 days after planting, and other primary lesions continued to develop for three to five weeks. As a rule, cotyledon lesions appeared first and hypocotyl infections a few days later. Out of doors, where there is a greater range in environmental conditions, the progress of the disease may be delayed.

RELATION OF RAINFALL TO THE DEVELOPMENT OF THE DISEASE.

A study of the effect of variation in the depth of rainfall on the development of the disease in the seed bed was made during the spring and summer of 1919 at Madison, Wis. Untreated seed of the Wisconsin Hollander variety, lot No. 2-18 previously referred to, was sown on May 14. A small percentage of the pods from which this seed was taken had shown black-leg lesions, and in greenhouse tests about 2 per cent of the seedlings had developed primary hypocotyl infections. The seed bed was divided into four plats, which were, respectively, handled as follows: Plat 1, exposed to natural weather conditions; plat 2, exposed as plat 1 and sprinkled several times each week during dry weather; plat 3, covered with a cold-frame during rains; plat 4, covered every evening and during rainy weather. The last treatment was devised to reduce the amount of dew which might form upon the plants. As a matter of fact, however, under the climatic conditions which prevailed during the trial, this artificial inclosure led to a greater accumulation of moisture upon these plants in plat 4 than upon those in plat 3. The protected

plats (Nos. 3 and 4) were watered artificially, care being taken to avoid splashing and the distribution of pycnospores.

A few infection centers appeared in all plats on or shortly after June 9. Following this date the appearance of new centers and subsequent spread was greatest in plat 2 and nearly as rapid in plat 1,

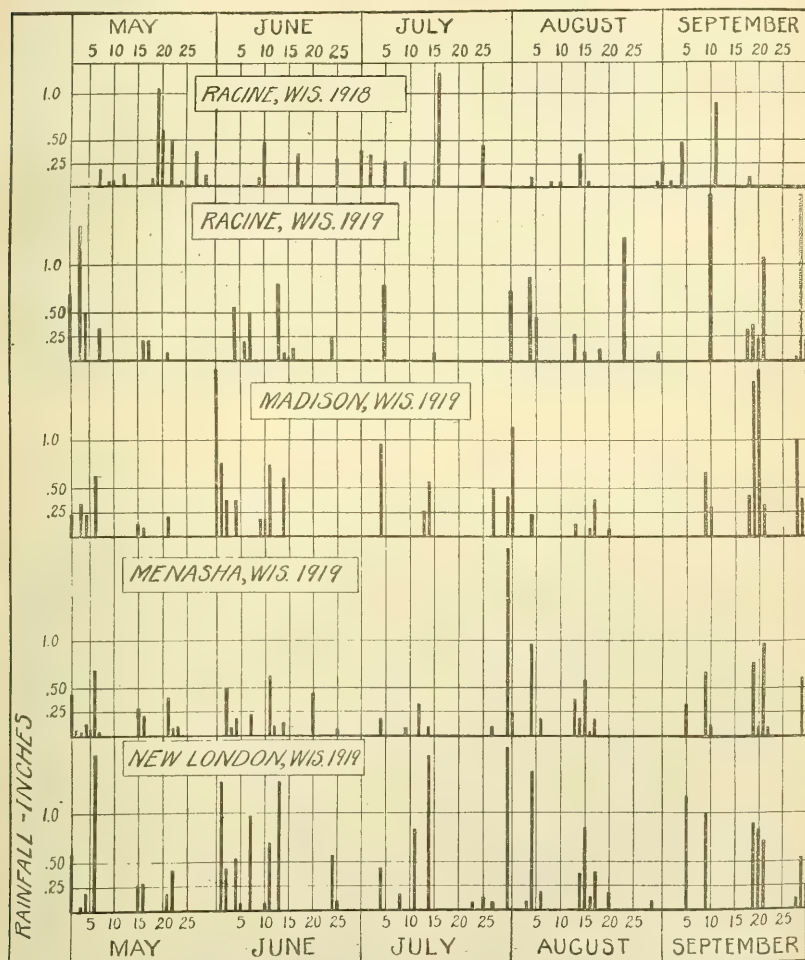


FIG. 1.—Precipitation records made by the United States Weather Bureau at Racine, Wis., in 1918 and 1919 and at Menasha, Wis. (nearest station to Appleton), and New London, Wis. (nearest station to Shiocton), in 1919.

while in the protected plats very little spread took place. The rainfall which occurred at Madison during the experiment is recorded in figure 1. The beds were kept under observation until August 4, which is about four weeks beyond the normal date for transplanting. The final estimate of the extent of the disease made at this time is presented in Table V. It is clear that where the splashing action of

rain was eliminated the spread of the disease was completely checked, while it was enhanced where artificial sprinkling was done. Although plat 3 was exposed to numerous heavy dews, these were apparently insufficient for the dissemination of spores for any appreciable distance.

TABLE V.—*Effect of variation in rainfall on the development of black-leg on cabbages in the seed bed at Madison, Wis., in 1919.*

Plat.	Treatment.	Extent of disease at the end of the experiment.	
		Number of plants examined.	Diseased (per cent).
No. 1.....	Exposed to natural rainfall.....	425	28.7
No. 2.....	Artificially sprinkled.....	174	37.9
No. 3.....	Covered during rains.....	359	.5
No. 4.....	Covered every evening and during rains.....	369	2.9

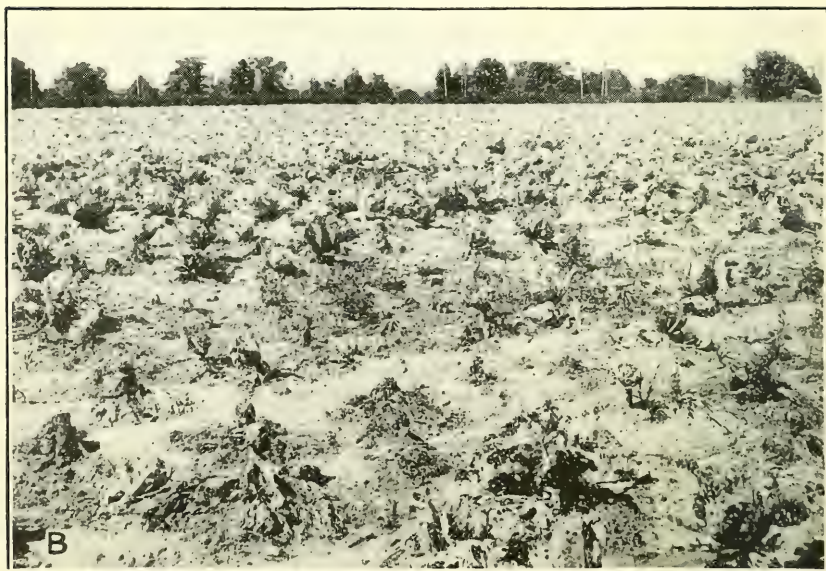
This experiment was repeated in 1920. Two lots of seed, one heavily infected (No. 2-19) and one mildly infected (No. 7-19), were planted in clean soil on May 12. Part of the plat was protected from rains during the growth of the plants, water being supplied artificially, with care to avoid splashing. After the first appearance of the disease on May 22, primary infections continued to develop on the cotyledons and at the base of the hypocotyl with about equal rapidity in the protected and unprotected portions of the plat. Pycnidia in these lesions were first noted on May 25. By June 14 practically all the primarily infected plants were dead, and each bore many mature pycnidia. The first secondary infections were noted on June 17, and from that time on the disease developed rapidly on leaves and stems of the plants in the unprotected portion of the plat. In an adjoining plat healthy plants were sprayed with a suspension of spores taken directly from lesions on infected plants. The disease appeared on these plants about 15 days later. It is thus to be expected that even under favorable conditions for dissemination and infection the appearance of secondary lesions would not ordinarily take place until two or three weeks after pycnidia appeared on plants infected from the seed. The plants in the plat were large enough for transplanting by the end of June, when they were pulled and examined for the presence of the disease. The results are given in Table VI. In spite of the fact that primary infections were very numerous in the case of the No. 2-19 seed very little spread to the aerial portions of surrounding plants occurred where the splashing of rain was avoided. Likewise, with the No. 7-19 seed the extent of the dissemination was



CABBAGE BLACK-LEG.

A.—Total loss of crop due to black-leg in spite of seed treatment with a 1:256 formaldehyde solution for 30 minutes. This field is typical of the epiphytotic of black-leg which developed in the Racine, Wis., district in 1918.

B.—The importance of seed-bed infection as influencing the subsequent development of black-leg in the field. The major portion of this field was planted from a healthy seed bed, but occasional lots of plants were used from a diseased bed. The row in the center of the illustration was planted with the latter. Note that practically every plant has wilted, while there is no evidence of damage by spread of the fungus from these plants to the adjacent rows. Photographed at Racine, Wis., September 30, 1917, about 12 weeks after transplanting and shortly before harvest.



**CABBAGE BLACK-LEG. RELATION OF SPREAD IN THE SEED BED TO
SUBSEQUENT DEVELOPMENT IN THE FIELD.**

These illustrations show the wide difference in destructiveness of the disease in plantings from the same seed bed made on different dates and in two neighboring fields. The seed was treated by the grower with 1:1,000 mercuric chlorid for 30 minutes before sowing. When the first planting was made, on June 11, practically no black-leg was noted in the seed bed, while on July 1, when the second planting was made, the disease had become widespread in the bed. Photographed at Racine, Wis., September 27, 1919, shortly before harvest.

A.—Planting of June 11. Of these plants 31 per cent were affected with black-leg, but only 4 per cent were prevented from heading by the disease. (See Table IX, field No. 1.)

B.—Planting of July 1 in the foreground. Of these plants 97 per cent were diseased and 60 per cent were prevented from heading by black-leg. The portion of the field in the background is an earlier planting from a different seed bed. (See Table IX, field No. 2.)

very small in the protected portion of the plat as compared with that in the portion exposed to natural rainfall.

TABLE VI.—*Effect of variation in rainfall on the development of black-leg on cabbages in the seed bed at Madison, Wis., in 1920.*

Seed lot.	Treatment.	Extent of disease at the end of the experiment.	
		Number of plants examined.	Diseased (per cent).
No. 2-19.....	Covered during rains.....	94	2.1
No. 2-19.....	Exposed to natural rainfall.....	117	81.1
No. 7-19.....	Covered during rains.....	135	4.4
No. 7-19.....	Exposed to natural rainfall.....	355	49.8

It is, therefore, undoubtedly true that in regions where cabbage plants are grown in open seed beds, variation in the rainfall which prevails during the period between the appearance of primary pycnidia and transplanting has a very great influence upon the development of black-leg. This fact should also be of value in checking the disease by avoiding the splashing of water where the plants are grown in covered coldframes or in greenhouses.

IMPORTANCE OF SPREAD IN THE SEED BED AS COMPARED WITH DISSEMINATION IN THE FIELD.

The question of the importance of the spread in the seed bed as compared with that in the field is, of course, to be considered in interpreting the development of the disease in midseason or later. It is natural to expect that the greatest amount of dissemination of the fungus from plant to plant takes place under the crowded condition in the seed bed and during the process of pulling and setting plants. Henderson (3) found that when plants showing no visible signs of the disease were taken from an infected seed bed and set into clean soil, a high percentage of them developed typical black-leg lesions on stems and roots within a few weeks. An instance is cited later in this paper (see fields 1 and 2 in Table IX; also Pl. II) where early and late planting from the same seed bed resulted in a wide difference in the destructiveness of the disease, due to the dissemination of the fungus after the first plants were removed. Numerous field observations have been made where black-leg wilt affected alternate plants in a row, as a result of the fact that one of the two droppers on the transplanting machine³ had set diseased plants. Many cases have

³The machine referred to is the transplanter commonly used in many sections for setting out cabbage, tobacco, and tomato seedlings. The setting is done by two persons, who place the plants alternately in the furrow, coincident with the release of a small quantity of water from a supply tank. One row is planted at a time.

been observed where alternate rows or groups of rows in the main field, from two different seed beds, resulted in one lot of plants wilting badly from black-leg, while the other was not affected. An instance of this is shown in Plate I, *B*. Thus, although exact experimental data have not been obtained, these general field observations indicate that, under Wisconsin conditions at least, the spread of the disease in the main field is not nearly so important as that in the seed bed or during transplanting.

SEED-BED TRIALS AT MADISON, WIS., IN 1919.

In order to supplement experiments performed in the laboratory, treated samples of seed from lots Nos. 2-18 and 3-18 were sown out of doors. Each of these lots contained a small percentage of infected seed. A level strip of silt-loam soil was selected, which had not grown cabbage for at least seven years. Single-row plats 7 feet long and 18 inches apart were used. Two-gram samples of each treatment were planted on May 10 and 12. The various treatments included with the final results obtained are given in Table VII.

In the check plats of untreated seed which were sown on May 14 the disease appeared on June 9 and was fairly well advanced by July 1, the normal time for transplanting. In all the treated plats the appearance of the disease was materially checked. On June 20 four centers of disease were found, one in each of the 12, 24, and 48 hour treatments of lot No. 2-18 with dry heat at 85° C., and one in the 24-hour dry-heat treatment of lot No. 3-18 at the same temperature. In the last case the disease had spread to 15 adjoining plants and to one of the adjoining plants in the case of another center. On June 27 one infected plant each was found in the formaldehyde 1:256 30-minute and the 1:128 1-hour plats. Thus, up to that date very little disease had developed, and had the plants been set in the field at this time, which would have been the normal time for transplanting, the disease would probably have been very successfully controlled.

In order to give the parasite all possible opportunity to develop in the plats, however, the plants were not disturbed until July 31, when they were all pulled and examined for black-leg. The data given in Table VII show that the disease continued to develop and spread from primary centers during July. Very few plats were entirely free from the disease, which is in general accord with the result of laboratory experiments.

TABLE VII.—*Development of black-leg in cabbage seed-bed plats sown with 2-gram samples of treated seed at Madison, Wis., in 1919.*

Type of treatment and temperature or concentration.	Length of exposure.	Effect upon badly infected seeds—viable fungus after treatment (per cent). ^a	Effect upon slightly infected commercial seeds.					
			Lot 2-18. ^b			Lot 3-18. ^b		
			Germination (per cent).	Seedling injury. ^c	Plants infected at the end of the experiment (per cent).	Germination (per cent).	Seedling injury. ^c	Plants infected at the end of the experiment (per cent).
Untreated.....	.....	75.3	92	○	29	96	○	7
Mercuric chlorid:								
Strength 1 to 1,000.....	30 minutes, rinsed.	16.6	92	○	16	.....	.....	.....
	30 minutes, rinsed.	12.0	88	○	62	.....	.....	.....
Strength 1 to 500.....	30 minutes, unrinsed.	15.3	72	⊖	22	.....	.....	.....
	1 hour, rinsed.	12.8	81	⊖	12	.....	.....	.....
Formaldehyde, not rinsed after treatment:								
Strength 1 to 256.....	30 minutes	.....	92	○	5	.....	.....	.....
	30 minutes	21.7	70	+	1	.....	.....	.....
Strength 1 to 128.....	1 hour.....	0	73	++	0	.....	.....	.....
	2 hours.....	0	46	++	2	.....	.....	.....
Hot, 1 to 128 formaldehyde:								
	1 minute.....	.....	45	++	4	.....	.....	.....
At 55° C.....	2 minutes.....	.....	46	++	2	.....	.....	.....
	5 minutes.....	.....	28	++	1	.....	.....	.....
	1 minute.....	.....	32	++	1	.....	.....	.....
At 60° C.....	2 minutes.....	.....	22	++	12	.....	.....	.....
	5 minutes.....	.....	20	++	0	.....	.....	.....
Hot water:								
	10 minutes.....	.....	83	○	0	.....	.....	.....
At 50° C.....	20 minutes.....	.....	81	○	0	.....	.....	.....
	30 minutes.....	.....	86	○	1	.....	.....	.....
	1 hour.....	0	85	○	0	.....	.....	.....
	5 minutes.....	20.0	81	⊖	0	.....	.....	.....
At 55° C.....	15 minutes.....	4.0	67	+	3	.....	.....	.....
	30 minutes.....	0	52	+	3	.....	.....	.....
	5 minutes.....	.....	59	+	3	.....	.....	.....
At 60° C.....	10 minutes.....	.....	34	+	0	.....	.....	.....
	15 minutes.....	.....	11	+	3	.....	.....	.....
Dry heat:								
	12 hours.....	32.6	88	○	19	92	○	7
	24 hours.....	17.7	85	○	31	98	○	24
At 85° C.....	48 hours.....	36.0	74	+	13	69	⊖	6
	72 hours.....	9.0	55	+	.....	74	⊖	.....
	96 hours.....	0	53	+	?	78	⊖	.....
	12 hours.....	25.0	78	+	.....	93	⊖	.....
At 90° C.....	24 hours.....	4.0	29	+	1	63	+	2
	36 hours.....	4.1	30	+	0	57	+	?
	12 hours.....	2.8	66	+	3	79	○	2
At 95° C.....	18 hours.....	0	33	+	2	.....	.....	.....
	24 hours.....	0	9	+	3	65	⊖	0

^a Data summarized from Tables I to IV, lots Nos. 4-18 and 1-19.^b Wisconsin Hollander variety, grown in 1918.^c Symbols used: ○=No injury; ⊖=slight; +=medium; ++=severe; +++=very severe.

It is evident from these trials that complete disinfection of cabbage seed infected with *Phoma lingam* without material reduction in germination is not to be hoped for. It is possible that some of the stronger treatments may be used with certain lots of seed, but their recommendation for general use is out of the question. Moreover, it is unsafe to assume that treatment, even if carried to the point where reduction in germination and seedling injury begins, can

always be relied upon to yield successful control. This point will be emphasized further by data from commercial trials presented in the following pages.

RESULTS WITH TREATED SEEDS IN COMMERCIAL FIELDS.

To determine the practical value of cabbage-seed treatment, several lots of commercially grown seed, varying in weight from 2 to 400 pounds, were treated before distribution in 1918 and 1919. All the seed except lot No. 14-18 was grown in the vicinity of Racine, Wis., and most of it was kept under the writer's observation. Varying amounts of black-leg prevailed on the seed plants, but in no case was a high percentage of pods infected. As noted before, the most seriously diseased lot, No. 2-18, when tested in the greenhouse showed primary infections on approximately 2 per cent of the plants. Unless otherwise stated, the seed was disinfected by the writer. It should be noted that in the cabbage sections where these observations were made, seed is sown in open beds about the first week of May, while transplanting is done as a rule between June 15 and July 5. Where possible, a survey of the seed beds was made before transplanting was begun, and final notes were taken in representative fields at the end of the season.

RESULTS IN 1918.

All of the fields under observation in 1918 were located at Racine, Wis., and were grown from seed which had been treated with a 1:256 formaldehyde solution for 30 minutes. Seed beds were sown about April 25. When a survey of the beds was made on June 14 the disease was already quite prevalent. Most of the transplanting was done between June 15 and June 30. There was no reason to believe that infection had originated otherwise than by way of the seed, since most of the beds were on soil new to cabbage or on which the crop had not been grown for several years. The rainfall records for this section (fig. 1) show that previous to June 14 the weather had been favorable for the rapid spread of the disease from primary centers.

As a result of the early spread of the fungus in the seed bed, the disease became very destructive as the season progressed. This development was confined largely to the home-grown seed, in spite of the fact that this had all been treated. A summary of the amount of disease in five representative fields at the end of the season is given in Table VIII. A typical field grown from this seed as it appeared at the end of the season is shown in Plate I, A. It was clear from this season's results that treatment with a 1:256 formaldehyde solution does not successfully control the disease when sufficient rainy weather prevails to bring about the dissemination of the fungus in the seed bed.

TABLE VIII.—*Development of cabbage black-leg in commercial fields planted with treated seeds in the Racine, Wis., district in 1918.*

Seed lot.	Treatment.	Field No.	Diseased plants.		Date of observation.
			Infected.	Prevented from heading.	
			<i>Per cent.</i>	<i>Per cent.</i>	
No. 2-17.....	1:256 formaldehyde, 30 minutes, rinsed	2	87	87	Nov. 2
No. 3-17 <i>a</i>	do.....	3	99	96	Do.
No. 3-17 <i>a</i>	do.....	1	99	91	Nov. 5
No. 4-17 <i>a</i>	do.....	1	74	14	Do.
No. 5-17.....	do.....	4	37	52	Oct. 30
No. 5-17.....	do.....	5	83	65	Nov. 1
Average, five fields.....			79.8	67.5	.....

a Treated by seed grower.

RESULTS IN 1919.

The observations were continued at Racine in 1919 and were extended to the Appleton and Shiocton districts in east-central Wisconsin, where certain quantities of the No. 2-18 and No. 3-18 lots of seed had been distributed. Most of the seed in all of these sections was sown about May 9. Because of the poor showing made with the formaldehyde solution in 1918, treatment with a 1:500 solution of mercuric chlorid for 30 minutes was recommended for general use in the spring of 1919. A small quantity of untreated No. 2-18 seed was sown in the Racine district on May 9. As already noted in the experiments conducted at Madison, the disease developed first and most rapidly from the untreated seed. When the beds at Racine were examined on June 12, black-leg had become widespread in the planting of untreated No. 2-18 seed. From the treated seed, however, very little of the fungus had developed at this date. Most of the transplanting was done within the next two weeks, and the disease was effectively checked in most fields, as shown by the results of a survey at the end of the season (Table IX). This was undoubtedly due to the fact that the development of primary infections was retarded and the number reduced by mercuric-chlorid treatment coupled with the fact that only two rainy periods occurred during the remainder of the month—one on June 13-16 and the other on June 24. (See fig. 1.)

In one bed under observation, where practically no black-leg was noted on June 11, the disease had become widespread by July 1. Two plantings were made from this bed, the first (field 1, Table IX) about June 12 and the second (field 2, Table IX) about July 2. A comparison of the two fields at the end of the season, as given in Table IX and illustrated in Plate II, brings out the effect of extensive spread of the disease in the seed bed previous to transplanting. In

general, however, the disease was not very prevalent in Racine fields at the end of the season. Where the mercuric-chlorid and dry-heat treatments were combined, very little disease developed, but since mercuric chlorid alone controlled the disease as well in this locality, the superiority of the double treatment was not demonstrated.

TABLE IX.—*Development of cabbage black-leg in commercial fields grown from treated seeds in Wisconsin in 1919.*

Locality and seed lot.	Treatment.	Field No.	Diseased plants.		Date of observation.
			Affected.	Prevented from heading.	
Racine:			<i>Per cent.</i>	<i>Per cent.</i>	
15-18 a.....	1 to 1,000 HgCl ₂ 30 minutes, rinsed.....	1	31.0	4	Sept. 19
15-18 a.....	do.....	2	97.0	60	Do.
13-18 a.....	1 to 500 HgCl ₂ 30 minutes, rinsed.....	3		11	Oct. 12
2-18 a.....	do.....	3		3	Do.
2-18 a.....	do.....	4	25	25	Oct. 13
2-18 a.....	do.....	5	2	2	Do.
2-18 a.....	do.....	6	11	11	Do.
2-18 a.....	do.....	7	4	4	Oct. 11
3-18 a.....	do.....	8		1	Sept. 19
3-18 a.....	do.....	9	2	2	Oct. 13
3-18 a.....	do.....	10	1	1	Do.
3-18.....	1 to 1,000 HgCl ₂ 20 minutes, rinsed, plus dry heat 85° C. for 72 hours.	11	1.2	1.2	Do.
3-18.....	1 to 1,000 HgCl ₂ 20 minutes, rinsed, plus dry heat 90° C. for 36 hours.	12	(b)	(b)	Do.
3-18.....	1 to 1,000 HgCl ₂ 20 minutes, rinsed, plus dry heat 95° C. for 12 hours.	13	.25	.25	Do.
Average, 5 fields, lot No. 2-18.	1 to 500 HgCl ₂ 30 minutes, rinsed.....		10.5	9.0	.....
Average, 3 fields, lot No. 3-18.	do.....		1.0	1.3	.....
Appleton:					
2-18.....	1 to 1,000 HgCl ₂ 30 minutes, rinsed.....	14	100	90	Oct. 10
2-18.....	do.....	15	100	68	Do.
2-18.....	1 to 500 HgCl ₂ 30 minutes, rinsed.....	15	92	63	Do.
Average, 3 fields, lot No. 2-18.	1 to 1,000 HgCl ₂ 30 minutes, rinsed.....				.....
	1 to 500 HgCl ₂ 30 minutes, rinsed.....		97.3	73.6	.....
Shiocton:					
3-18 a.....	do.....	16	50 to 90	50 to 90	Oct. 11
3-18 a.....	do.....	17	50 to 90	50 to 90	Do.
3-18 a.....	do.....	18	50 to 90	50 to 90	Do.
14-18 a.....	1 to 256 HCHO 30 minutes, rinsed.....	19		90	Do.
Average, 3 fields, lot No. 3-18.	1 to 500 HgCl ₂ 30 minutes, rinsed.....		50 to 90	50 to 90	.....

a Disinfected by seed grower.

b One diseased plant found in a 3-acre field.

Conditions were decidedly different in the Appleton and Shiocton districts. A survey showed that the disease had developed into a uniformly severe epiphytotic in fields of both localities grown from Nos. 2-18 and 3-18 seed (Table IX). Unfortunately the seed beds were not examined, but the even distribution and advanced stage of the disease left no doubt that the fungus had become widespread before transplanting. In one field at Shiocton where the formaldehyde treatment was used the disease was not controlled. A comparison of precipitation records (fig. 1) taken at Menasha (near

Appleton) and at New London (near Shiocton) with those taken at Racine shows that the rainy periods from May 15 to June 15 were more numerous and as a rule of longer duration in the first two localities. It may be inferred from this that there was more opportunity for pycnospore dissemination and subsequent infection at Appleton and Shiocton than at Racine. In view of the evidence already presented as to the importance of rainfall in this connection, it is not improbable that this factor was the critical one in determining the difference in development of the disease in the three localities mentioned.

These field trials justify the conclusion, as did those made in the laboratory, that neither formaldehyde nor mercuric-chlorid treatment of cabbage seed, even if carried to the point where seed injury occurs, is a sure preventive of black-leg. Such seed treatment does, however, greatly reduce the development of primary infection. This result, if coupled with favorably dry weather during the seed-bed period, may suffice to give practical disease control, but with more abundant rains during this period the disease may develop to a serious extent. It should be recalled in this connection that seed treatment with corrosive sublimate is also a successful preventive of seed-borne black-rot organisms (12). Since cabbage-seed treatment is a useful precaution in these two possible directions and is so simple and inexpensive, it is strongly recommended. In the light of our present knowledge, soaking in a 1:1,000 mercuric-chlorid solution for 30 minutes followed by rinsing in clean water is safest for general use.

IMPORTANCE OF DISEASE-FREE SEEDS.

The fact has been brought out that in spite of any practicable seed treatment abundant rainfall may cause sufficient spread of the black-leg fungus from the few primary infections appearing in the seed bed to produce an epiphytotic. Since, therefore, in practice one can not rely with confidence upon cabbage-seed treatment for the sure elimination of the black-leg organism from infected seed, it is obviously important to give increased attention to the securing of seed free from *Phoma* infection. Experience in Wisconsin has shown that to accomplish this the crop must be kept clean from the outset; in other words, disease-free "mother seed" must be used on clean soil. A large percentage of American cabbage seed is now grown in two sections, eastern Long Island, N. Y., and in the Puget Sound region of western Washington. In the latter section "mother seed" is usually obtained from another locality, most commonly from Long Island, Denmark, or England. In the Long Island section local or foreign grown "mother seed" is used. In either case the danger of introducing black-leg into the seed crop through infected seed is very great, since practically none of the growers practice seed treatment.

This was brought very forcibly to the attention of the writer in August, 1920, when such a case was described by a seed contractor in one of the mentioned localities. Stock "mother seed" of a given variety which later was proved to be infected with *Phoma* was distributed among several seed growers in 1919. A trial row was planted in 1920 by the contractor, and when examined in August by the writer the plants showed a high percentage of black-leg. One of the 1919 plantings for seed examined in 1920 showed black-leg infection on 25 per cent of the seed plants,⁴ while the several other fields from the same "mother seed" were undoubtedly infected. Thus, approximately 2,000 pounds of commercial seed became infected as a result of the introduction of the parasite on a small quantity of stock seed. Much of such seed infection can be prevented by growing stock seed from seed heads carefully selected for freedom from disease followed by careful inspection during the following season. By applying this method in Wisconsin black-leg has been successfully avoided and comparatively large quantities of disease-free "mother seed" have been produced.

Black-leg has not as yet been reported from the Puget Sound region, and an inspection of more than 30 seed fields in that region in June, 1919, yielded no sign of the disease. Inasmuch as most of these seed fields are started from "mother seed" grown in the East or abroad and none of the growers practice seed treatment, it is inevitable that some infected seed is sown. It would seem from comparison with our Wisconsin experience that this absence of the disease, as noted in the seed fields, must therefore be attributed to local climatic conditions restrictive to the development of the fungus. This was rendered the more probable by the results previously recorded (11) with some Wisconsin-grown seed known to be infected with *Phoma*. This was seed No. 2-18, which, as used in Wisconsin, resulted in high percentages of infection before the end of the season (see Tables VII and IX). Of this, 2 pounds were sent to the Puget Sound section for propagation after treatment for 30 minutes with mercuric chlorid. This was sown at Mount Vernon, Wash., about May 25, and when it was inspected seven weeks later, July 14, only four infected seedlings were found in the entire bed. These were evidently cases of primary infection with no spread whatever to the adjacent plants. In 1920, samples from two lots of badly infected seed were sown in this locality and portions of the same lots sown at Madison, Wis. In the latter region the fungus appeared in numerous primary infections within two weeks, and the disease had become widespread by transplanting time (see Table VI). Since

⁴ The writer is indebted to Mr. I. H. Vogel, of Cornell University, for information regarding this field.

personal inspection by the writer of the western plantings was impossible, notes were taken by a careful grower, aided by preserved specimens of the disease forwarded to him. Although the plantings were kept under observation until October, he noted no development of the disease, thus apparently confirming the observations of the previous season.⁵ It is possible that the dry weather which usually prevails in western Washington from about June 10 to September 1 (5) may account for the lack of development of black-leg. This matter should, therefore, be kept under observation for a period of years, since it is obvious that relatively minor variations in amount and date of rainfall from season to season may materially affect the development of the disease. In any case, this experience emphasizes the necessity of greater attention than has heretofore been given to the importance and practicability of securing cabbage seed free from black-leg infection.

SUMMARY.

(1) Cabbage black-leg is a disease of increasing economic importance, and its appearance in epiphytotic form has been generally associated with the use of infected seed.

(2) Experimental treatments of infected and commercial seeds with formaldehyde solution, mercuric-chlorid solution, hot water, and dry heat have shown that the fungus can not be entirely eradicated from infected seeds by any of these fungicides without materially reducing germination and causing injury to seedlings.

(3) When infected seed is used primary lesions appear as a rule on a small percentage of seedlings in the seed bed 10 days to several weeks after planting.

(4) The subsequent dissemination and development of the fungus are favored by spattering water and atmospheric humidity. Consequently, where the seed bed is located in the open, spread from such primary centers to surrounding plants is dependent upon the amount of rainfall and of humid weather which prevails during the seedling stage.

(5) The dissemination of the fungus in the seed bed or during transplanting appears to be of much greater importance than its spread in the main field.

(6) Seed-bed trials showed that the disease was checked by seed treatment, but was not completely controlled even when the treatment was carried beyond the point where seed injury resulted.

(7) In 1918 an epiphytotic of black-leg developed at Racine, Wis., from seed treated with a 1:256 formaldehyde solution for 30 min-

⁵ Comparative trials in Wisconsin, at Mount Vernon and Madison, were continued in 1921 with confirming results. (See Walker, J. C., and Tisdale, W. B. Further notes on the occurrence of cabbage black leg Abstracts of papers presented at the Toronto meeting of the American Phytopathological Society, Dec., 1921. *In* *Phytopathology*, v. 12.)

utes. This occurred under weather conditions favorable to the disease, owing to frequent rains.

(8) In 1919, in the same locality, under dry weather conditions, the disease was quite effectively controlled by seed treatment, soaking in 1:500 mercuric chlorid for 30 minutes, followed by rinsing in clean water. At Shiocton and Appleton, Wis., where longer and more frequent rainy periods prevailed between the appearance of primary centers and transplanting, serious epiphytotics developed from the same lots of seed as used in the Racine district. It was thus shown that even this strong treatment was insufficient to control the disease effectively when climatic conditions favored the rapid spread of the fungus from primary centers.

(9) Since treatment reduces the number of primary centers and retards their development somewhat and since it is also a preventive against seed-borne black-rot organisms, it should be recommended. The limitations to success in the control of black-leg, however, should be recognized.

(10) Trials have developed the fact that different lots of cabbage seed may vary considerably in their relative susceptibility to injury from seed-disinfection treatments. Stronger treatment than a 1:256 or 1:240 solution of formaldehyde or a 1:1,000 solution of mercuric chlorid for 30 minutes followed by rinsing is unsafe for general use. Of these two treatments, the mercuric chlorid seems to be slightly superior in eradicating the fungus. It is true, however, that many lots of seed will stand much more severe treatment, especially with mercuric chlorid, but in the event of such treatment preliminary tests should always be made.

(11) In view of the limitations of treatment in controlling black-leg special attention should be given to securing disease-free seed.

LITERATURE CITED.

- (1) ATANASOFF, DIMITAR, and JOHNSON, A. G.
1920. Treatment of cereal seeds by dry heat. *In Jour. Agr. Research*, v. 18, no. 7, p. 379-390, pl. 48-49. Literature cited, p. 388-391.
- (2) HARRINGTON, GEORGE T., and CROCKER, WILLIAM.
1918. Resistance of seeds to desiccation. *In Jour. Agr. Research*, v. 14, no. 12, p. 525-532.
- (3) HENDERSON, M. P.
1918. The black-leg disease of cabbage caused by *Phoma lingam* (Tode) Desmaz. *In Phytopathology*, v. 8, no. 8, p. 379-431, 10 fig. Literature cited, p. 431.
- (4) HUTCHINSON, H. B., and MILLER, N. H. J.
1909. Direct assimilation of ammonium salts by plants. *In Jour. Agr. Sci.*, v. 3, pt. 2, p. 179-194, 2 fig., pl. 14. References, p. 193-194.
- (5) KINCER, JOSEPH BURTON.
1919. Seasonal distribution of precipitation and its frequency and intensity in the United States. *In Mo. Weather Rev.*, v. 47, no. 9, p. 624-631, 17 fig.
- (6) MCALPINE, DANIEL.
1901. Fungus Diseases of Cabbage and Cauliflower in Victoria, and Their Treatment. 38 p., 11 pl. (1-3 col.). Melbourne.
- (7) MANNS, T. F.
1911. Black-leg or *Phoma* wilt of cabbage. *In Phytopathology*, v. 1, no. 1, p. 28-31, 2 pl.
- (8) NORTON, J. B. S.
1919. Hot water seed treatment for black leg of cabbage. (Abstract.) *In Phytopathology*, v. 9, no. 1, p. 50-51.
- (9) ROBINSON, T. R.
1910. Seed sterilization and its effect upon seed inoculation. U. S. Dept. Agr., Bur. Plant Indus. Circ. 67, 11 p.
- (10) WAGGONER, H. D.
1917. The viability of radish seeds (*Raphanus sativus* L.) as affected by high temperatures and water content. *In Amer. Jour. Bot.*, v. 4, no. 5, p. 299-313, 1 fig. Literature cited, p. 312-313.
- (11) WALKER, J. C.
1920. Occurrence and control of black leg of cabbage. (Abstract.) *In Phytopathology*, v. 10, no. 1, p. 64.
- (12) ——— and TISDALE, W. B.
1920. Observations on seed transmission of the cabbage black rot organism. *In Phytopathology*, v. 10, no. 3, p. 175-177.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY



UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1030

Joint Contribution from the Bureau of Markets and
Crop Estimates, H. C. TAYLOR, Chief, and the Bu-
reau of Plant Industry, WM. A. TAYLOR, Chief



Washington, D. C.

March 10, 1922

MEADE COTTON, AN UPLAND LONG-STAPLE VARIETY REPLACING SEA ISLAND.

By G. S. MELOY, *Bureau of Markets*, and C. B. DOYLE, *Bureau of Plant Industry*.

CONTENTS.

	Page.		Page.
Need of replacing Sea Island cotton.....	1	Extending the cultivation of Meade	
Decline of the Sea Island industry.....	2	cotton in 1920.....	11
Value of Meade cotton as a substi- tute for Sea Island demonstrated.....	2	Production of Meade cotton in 1920.....	14
Origin of the Meade variety.....	3	Cultivation of Meade cotton.....	15
Description of the variety.....	4	Closer spacing with Meade cotton.....	16
Meade cotton adapted to Sea Island conditions.....	4	Problem of seed supply of Meade cotton.....	18
Increasing seed supplies in 1918.....	6	Selection necessary to maintain uni- formity.....	19
Experiments with Meade cotton in 1917 and 1918.....	9	Spinning tests of Meade cotton.....	20
Work with Meade cotton in 1919.....	10	Conclusions.....	23
		Literature cited.....	24

NEED OF REPLACING SEA ISLAND COTTON.

Since the arrival of the boll weevil in the Sea Island cotton districts of the southeastern United States the production of this valuable fiber has been rapidly declining. The large growth of the plants and the late maturity of the crop render Sea Island cotton particularly susceptible to injury by the weevil. From an average yearly production of 90,000 bales in the 10 years before 1917, less than 2,000 bales have been reported from the 1920 crop.

For several years before the boll weevil reached the Atlantic seaboard it was evident that this insect was likely to destroy the Sea Island cotton industry. Efforts were made to develop earlier strains of the Sea Island type in the hope that production might be continued, but in this direction no practical results have been obtained. During the same period experimental plantings of Meade cotton, a new variety of the Upland type developed in northeastern Texas, gave indications of being adapted to the southeastern conditions and showed promise of success as a substitute for Sea Island cotton. Meade cotton is an early-maturing long-staple Upland variety producing a

fiber under favorable conditions $1\frac{1}{8}$ inches long, of fine texture and quality, and remarkably like the Sea Island cotton. Moreover, on account of its nearly smooth seeds Meade cotton can be handled on the regular Sea Island gins.

DECLINE OF THE SEA ISLAND INDUSTRY.

The spread of the boll weevil to include the entire Sea Island section of the Southeastern States was foreseen several years ago, and it was generally conceded that the rank-growing, late-fruited habits of the Sea Island cotton would make it particularly susceptible to injury from this pest. That this prediction is being rapidly fulfilled and that the complete destruction of the Sea Island industry is threatened are indicated by the rapid decline in the production of this fiber, as follows:

	Bales.		Bales.
1916-----	117, 559	1919-----	6, 916
1917-----	92, 619	1920-----	1, 868
1918-----	52, 208		

With the increasing demand for high-grade fiber for war purposes the situation became acute, and efforts to preserve the industry were made by the United States Department of Agriculture in cooperation with the State agricultural experiment stations in the Sea Island belt. Only two avenues of approach seemed open—either the development of an early strain of Sea Island cotton, from which profitable crops could be grown in the presence of the boll weevil, or the substitution of an Upland variety that combined the superior cultural features of this type with a fiber comparable in length and fineness to the Sea Island.

VALUE OF MEADE COTTON AS A SUBSTITUTE FOR SEA ISLAND DEMONSTRATED.

The favorable results from the first experimental plantings in 1916 with Meade cotton on the Sea Islands around Charleston, S. C., led to small commercial plantings the following season at several points in Georgia. Since 1917 the area devoted to Meade cotton has been steadily increasing, but not so rapidly as was at first expected, owing to the failure of many farmers to appreciate the necessity of separating the fields of Meade from other cotton and ginning the crop on a clean gin. The consequent mixing and loss of purity of the stock have prevented the rapid increase in supplies of pure seed that would have been possible if the necessary precautions had been taken.

During the five years that Meade cotton has been grown in the Southeastern States it has continued to demonstrate its value as a substitute for the Sea Island. Where definite comparisons have been possible it has produced at least twice as much as the Sea Island

cotton and not less than the short-staple cotton varieties under the same conditions. The price relation of Meade fiber to the fiber of short-staple varieties may be expected to be at least two to one in favor of the Meade, whatever the price of short cotton may be.

ORIGIN OF THE MEADE VARIETY.

The Meade cotton originated from a selection made in 1912 at Clarksville, Tex., in a field of a variety locally called Blackseed, or Black Rattler, but not the same as the varieties that have carried these names in other parts of the cotton belt (14, 1918, p. 3; 1919, p. 26; 1920, p. 4).¹

The possibility of producing from this stock an Upland variety that would rival the Sea Island cotton in length and fineness of staple and at the same time possess the cultural advantages of an Upland cotton appealed very strongly to Mr. Rowland M. Meade, at that time an assistant in cotton breeding in the Bureau of Plant Industry. Three generations of progenies from select individuals had been grown, and a superior stock had been separated before the sudden death of Mr. Meade in 1916. The new variety was named for Mr. Meade as a tribute of the personal regard of his associates and to commemorate his services as a plant breeder.²

MEADE COTTON NOT A HYBRID.

Unauthorized statements have appeared in newspapers and agricultural journals referring to Meade cotton as a new early Sea Island variety or as a hybrid between the Upland and Sea Island types, but such accounts are erroneous. Meade cotton was not produced by hybridization, but is the result of the discovery and continued selection of a superior type. It has been assumed that a variety like the Meade must be a hybrid because the plant is like Upland and the lint like Sea Island, but this reasoning is not in accord with the facts.

Many attempts have been made to combine the superior fiber of the Sea Island or Egyptian types of cotton with the desirable cultural characters of the Upland varieties. While crossing is readily accomplished and the results frequently appear promising in the first generation, no hybrid stock has yet been developed that was sufficiently uniform to justify commercial planting. Meade cotton is a separate and distinct variety that combines the superior cultural features of the Upland type with a long and silky fiber like that of the Sea Island. The uniformity of Meade cotton at once places it in a different class from any stocks known to have a direct hybrid origin.

¹ The serial numbers (*italic*) in parentheses refer to "Literature cited" at the end of this bulletin.

² This paragraph and a few others are adapted with slight revision from an article by O. F. Cook (5).

DESCRIPTION OF THE VARIETY.

The following description of the Meade variety has been published (8) in connection with the distribution of seeds:

Plant erect, of average height, with regular internodes of medium length on both the main stalk and on the vegetative branches. Internodes of the fruiting branches rather long, with little tendency to take the shortened "cluster" form. Leaves of medium size and rather thin texture, not deeply cut, a larger proportion with only three lobes than in most varieties. Involucral bracts of medium size, not exceeding the bolls, with 10 slender teeth. Bolls medium size, with a thin bur, opening readily even under humid conditions. Seeds large, about 3.000 to the pound, nearly naked after the lint has been removed, brownish black, slightly tufted at either end. Lint $1\frac{1}{2}$ to $1\frac{1}{4}$ inches in length, uniform, with good luster, slightly heavier bodied than Sea Island cotton, scarcely distinguishable from Sea Island when properly ginned. Lint percentage, 26; lint index, 5.5.

VEGETATIVE CHARACTERS LIKE SHORT-STAPLE COTTON.

Though not without distinctive plant characters, Meade cotton has the general appearance and behavior of many of the Upland long-staple and short-staple varieties; for the shape of the plant, the character of the leaves, the earliness in fruiting, and the size of the bolls are very similar to the ordinary Upland sorts. The fiber, however, is so long and fine that when ginned on a roller gin it is freely accepted on the Sea Island markets on a par with the true Sea Island cotton.

As grown in the Southeastern States, Meade cotton or the "long short cotton," as it is sometimes called by the farmers, produces a fiber from $1\frac{1}{2}$ to $1\frac{3}{4}$ inches in length under favorable conditions, seldom falling below $1\frac{7}{16}$ and sometimes attaining $1\frac{3}{4}$ inches. (Pl. I.)

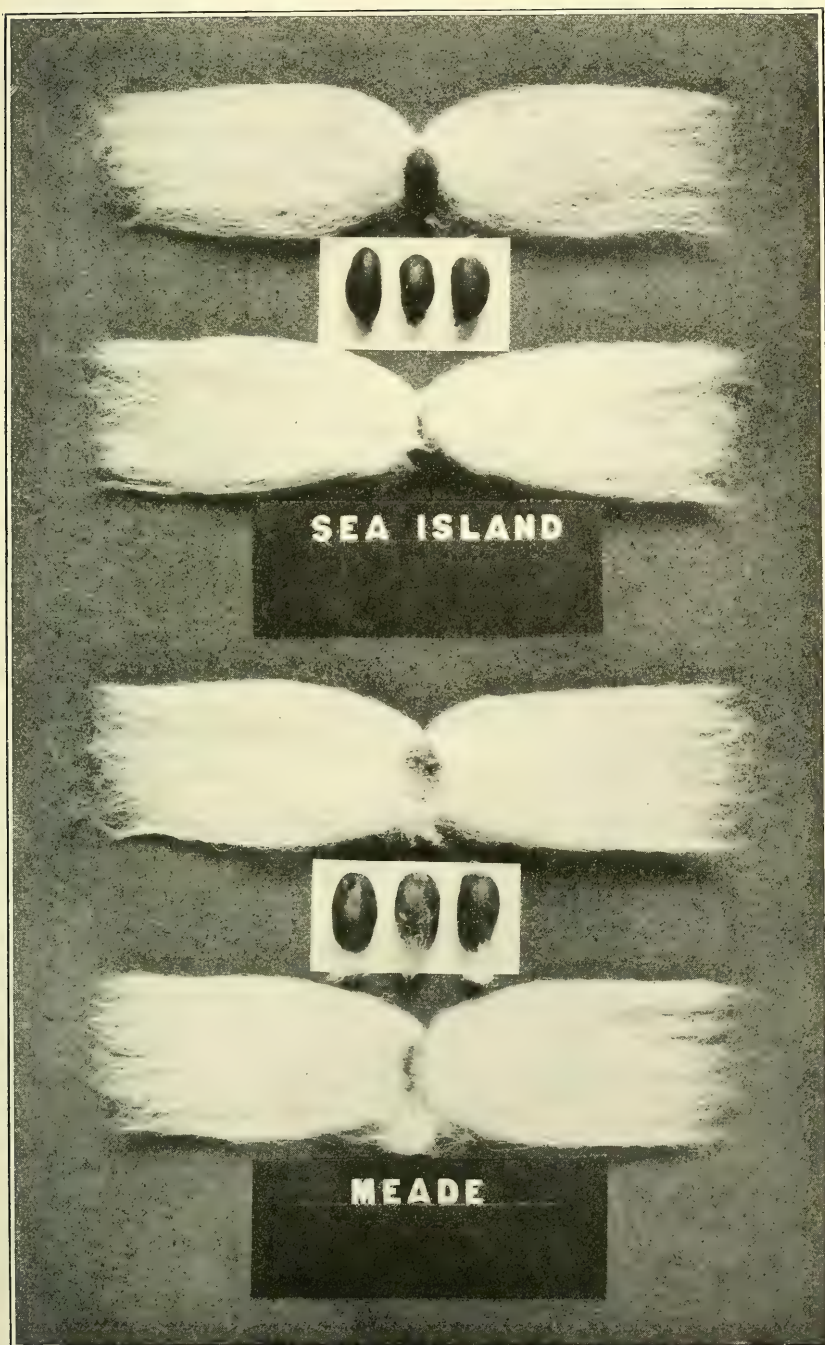
The fiber on the seed of the Meade variety shows little tendency to "butterfly," that is, to shorten the fibers at the base of the seed, which was one of the undesirable traits of the older Upland long-staple varieties, such as the Floradora, Sunflower, and Allen.

The seeds are large and brownish black, naked on the sides, like Sea Island and Egyptian, with a small tuft of white fuzz at either end. (Pls. I and II.)

MEADE COTTON ADAPTED TO SEA ISLAND CONDITIONS.

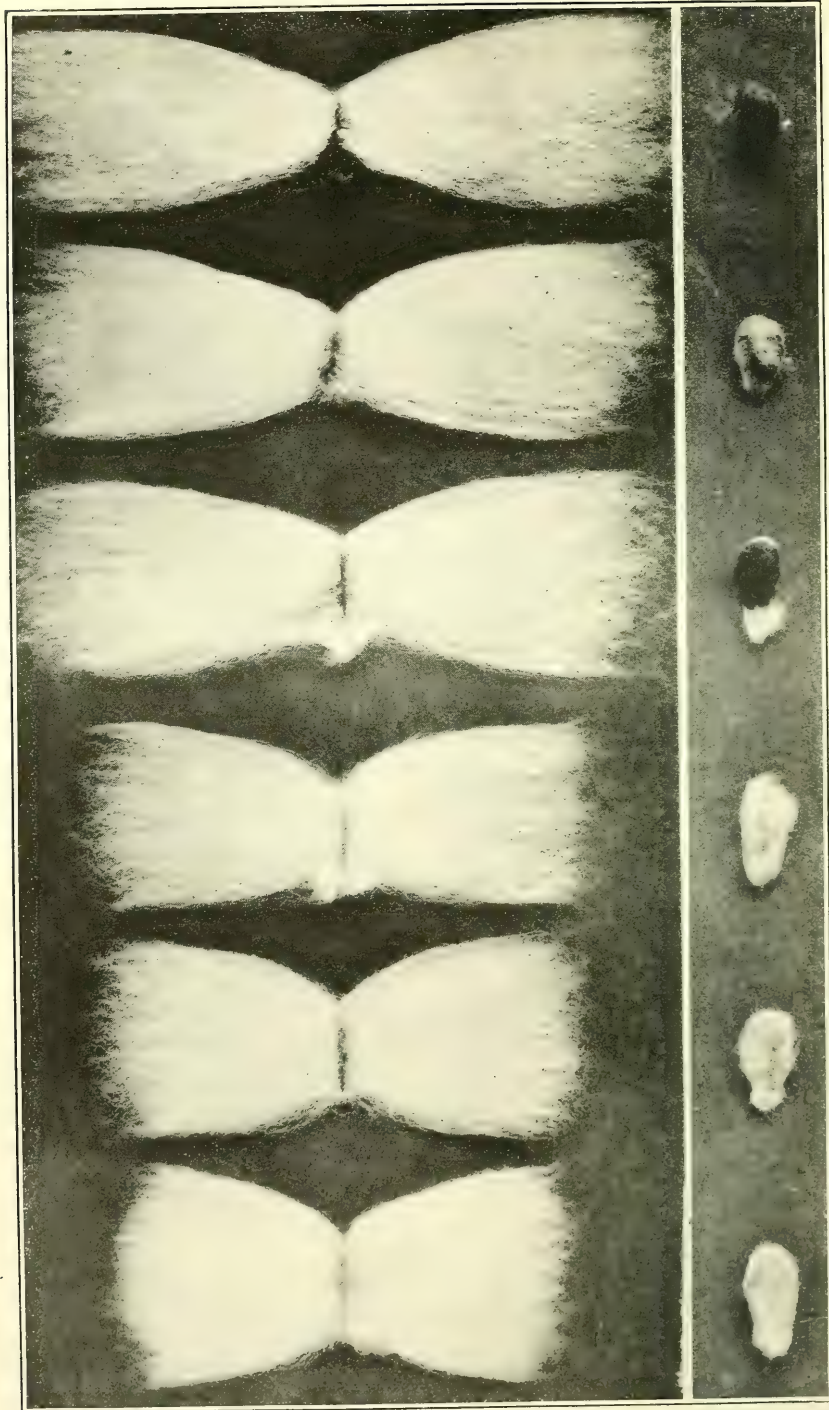
With its early, quick-fruited habits, long and silky fiber, and smooth seeds, permitting the use of roller gins, the new Meade variety seemed to be the only Upland cotton promising any measure of success as a substitute for Sea Island cotton, and with these facts in view work was begun five years ago to adjust the new variety to the local conditions on the Sea Islands of South Carolina.

In 1916 small experimental plantings of the Meade cotton were made on these islands for the purpose of studying the behavior of the variety under eastern conditions. Promising results were se-



COMBED LINT AND SEEDS OF SEA ISLAND AND MEADE COTTON.

(Natural size.)



COMBED LINT AND SEEDS OF SIX SUPERIOR VARIETIES OF COTTON.

In order from top these varieties are Sea Island, Egyptian (Pima), Meade, Durango, Acala, and Lone Star. All of these varieties excepting the Sea Island have been developed by the United States Department of Agriculture and are being extensively grown in different parts of the American cotton belt. (Natural size.)

cured, and in 1917 the experimental plantings were extended throughout the Sea Island district of Georgia in order to ascertain the behavior of this cotton under boll-weevil conditions in comparison with that of the Sea Island type. That these preliminary plantings showed additional promise for the variety is shown by the results obtained.

At Thomasville, Ga., under conditions of extreme boll-weevil infestation, 1 acre of Sea Island and Meade cotton was planted in alternate blocks of four rows. The Meade yielded at the rate of 1,499 pounds of seed cotton per acre and the Sea Island at 501 pounds. At Valdosta, Ga., only small plantings were made to ascertain the comparative earliness of the two types. By September 13 the Meade test rows had yielded 230 pounds of seed cotton, but it was not until September 28 that 117 pounds of seed cotton were secured from the Sea Island rows. In addition to the difference in earliness and yield shown in this test, Table 1 presents the results obtained in a comparison of Meade and Sea Island bolls.

TABLE 1.—*Comparison of Meade and Sea Island bolls grown in alternate rows at Valdosta, Ga., in 1917.*

Variety.	Weight of 10 4-locked bolls (grams).		Percentage of lint.	Lint index.	Number of 4-locked bolls to—			Weight of seed from bale of cotton (pounds).
	Total.	Lint only.			Pound of seed cotton.	Pound of fiber.	500-pound bale.	
Meade.....	65.70	17.6	26.8	5.45	69	257	128,500	1,365
Sea Island.....	35.75	10.9	30.7	4.93	126	412	206,000	1,111

This experiment shows that it required 57 more bolls of Sea Island than of Meade cotton to make a pound of seed cotton, 155 more bolls of Sea Island to make a pound of fiber, and 77,500 more bolls of Sea Island to make a 500-pound bale. (Pl. III.)

While the ratio of fiber to seed in the Sea Island was 30.7 per cent and in the Meade 26.8, the actual weight of the fiber from 10 four-locked bolls of each was much greater for the Meade on account of the larger size of the Meade seed.

In addition to these advantages of the Meade over the Sea Island, it should be remembered that a large percentage of the Sea Island bolls have only three locks, while most of the Meade bolls have four locks and a fair percentage have five locks.

At Statesboro, Ga., 5 bushels of Meade seed were used to plant a block of 8 acres. The cooperator was a prominent Sea Island cotton grower, producing that year some 40 bales of this fiber. The 8 acres of Meade cotton produced 6 bales of fiber, and both the Sea Island and Meade crops were ginned on the same gin and baled in the same

manner. Both crops were shipped to Savannah, and samples were submitted to Sea Island cotton buyers with a note that this cotton was offered as a substitute for the Sea Island. It was stapled at $1\frac{1}{8}$ inches and sold for $73\frac{1}{2}$ cents a pound, which was one-half cent a pound premium over the prevailing price for the best Georgia Sea Island on that day.

The report of this sale naturally attracted the attention of cotton growers throughout the Sea Island belt, and the United States Department of Agriculture received many requests for seed of the Meade variety. At that time the supply of this seed was very small, and no general distribution could be made, but it was hoped to produce from the 1918 plantings enough seed for a large acreage in 1919.

INCREASING SEED SUPPLIES IN 1918.

The preliminary experiments having shown much promise for the Meade variety as a practical substitute for the Sea Island cotton, plans were laid for a rapid increase in the seed supply from the 1918 plantings.

Several reliable farmers scattered throughout the Sea Island district of Georgia and South Carolina were willing to cooperate with the United States Department of Agriculture in its efforts to provide an adequate supply of pure seed. Sufficient seed was furnished by the department to plant from 5 to 75 acres, under an agreement that to prevent possible crossing with other varieties the plantings would be made in isolated fields at least 300 yards from any other kind of cotton; or if this was not practicable, 50 or 60 rows of corn should be grown between the Meade and any other variety. Representatives of the department were to visit the plantings during the season for the purpose of roguing the fields or pulling up the off-type plants and furnishing information in the methods of seed selection. The department was to receive one-third of the seed grown from the crop, while the farmer retained the lint and the remaining two-thirds of the seed for his own use or to sell to his neighbors and thus make it possible to establish community production of Meade cotton and maintain adequate supplies of pure seed.

FARMERS FAIL TO ISOLATE PLANTINGS.

An inspection of these plantings in June of that year showed that while some of the farmers had observed the precaution of isolating the Meade field many of the plantings were not separated from other cotton and on that account were useless for pure-seed purposes. Some of the plantings were close to Sea Island fields and others to short-staple Upland varieties or mixed stocks. In several cases where poor stands of the Meade had been secured replanting had been done with Sea Island seed. In one instance 26 acres of Meade cotton had been flanked on one side with a field of Sea Island and on the other by short cotton.

SMALL ACREAGE OF PURE SEED IN 1918.

While not more than 250 acres, all told, of the Meade plantings in 1918 had been sufficiently separated from other kinds of cotton to insure their freedom from possible hybridization, it was thought that with careful handling sufficient seed of good quality would be available for a large acreage in 1919. With the assistance of the farmers these fields were carefully inspected and all hybrids and off-type plants were destroyed.

Though familiarity with Meade cotton is usually necessary to distinguish some of the off-type plants, the hybrids between the Sea Island and Meade cottons are easily recognized by their larger and deeper cut leaves, in which they resemble the true Sea Island. Once these plants are pointed out and their contrasting features noted they are easily recognized, even by those who have not done any special breeding work. (Pls. IV and V.)

SELECTION WORK CONTINUED IN THE HARVEST SEASON.

During the harvest season the plantings that had been sufficiently isolated were again visited for the purpose of instructing the farmers in the methods of seed selection for breeding stocks. From 100 to 200 plants that conformed to the Meade type were selected from each of the isolated fields for separate picking and ginning, the seed of which was to be used for a seed-increase block the following season. In addition to this bulk selection, a number of especially desirable plants were selected for progeny-row planting at each point.

The bulk of the Meade crop was to be ginned on the regular commercial Sea Island gins most convenient to the plantings, except in an experiment near Sylvester, Ga., where a new roller gin had been installed for ginning only Meade cotton. The farmers were warned against the danger of the Meade seed becoming mixed with that of the Sea Island at the gins unless special care were taken to have the gins thoroughly cleaned before the Meade cotton was put through.

GINNING COMPLAINTS FROM MEADE GROWERS.

During the ginning season complaints were received from some of the Meade cotton growers that the Sea Island ginners were objecting to Meade cotton on account of the large size of the seed, which failed to pass through the seed grids (manufactured especially for the small Sea Island seed) as rapidly as the seed of the Sea Island and consequently slowing down the ginning process.³

³ This difficulty in ginning was subsequently met by one of the manufacturers of roller gins, who put a new seed board or grid upon the market designed especially for ginning Meade cotton. (Pl. VI.) This seed board has fingers instead of ribs, doing away with the edge that formerly prevented the passage of seed near the stripper or hacker bar. The fingers are also farther apart than the ribs in the seed board used for Sea Island ginning. It has since been ascertained that moving the ordinary seed grid back from the stripper bar from one-half to three-quarters of an inch permits the Meade seed to fall through without difficulty.

There was no objection to ginning the Meade cotton in the early part of the ginning season, before the Sea Island crop began to come in, but when the latter cotton arrived the Meade was either held up for a lull in the Sea Island ginning or the ginners insisted upon holding the Meade until after the disposal of the Sea Island crop.

On account of such difficulties, many of the farmers who took the trouble to go to the gins personally still failed to carry out the instructions for clean ginning. With the exception of the few bales that were put through before the arrival of the Sea Island crop much of the Meade crop was ginned at intervals between the operations for Sea Island cotton, and no adequate precautions were taken to have the gins cleaned.

RESULTS IN 1918 IN SEA ISLAND DISTRICTS.

Though the failure of the ginners and farmers to cooperate at the gins restricted the quantity of pure Meade seed available for planting in 1919, the results that were secured in the field continued to be encouraging.

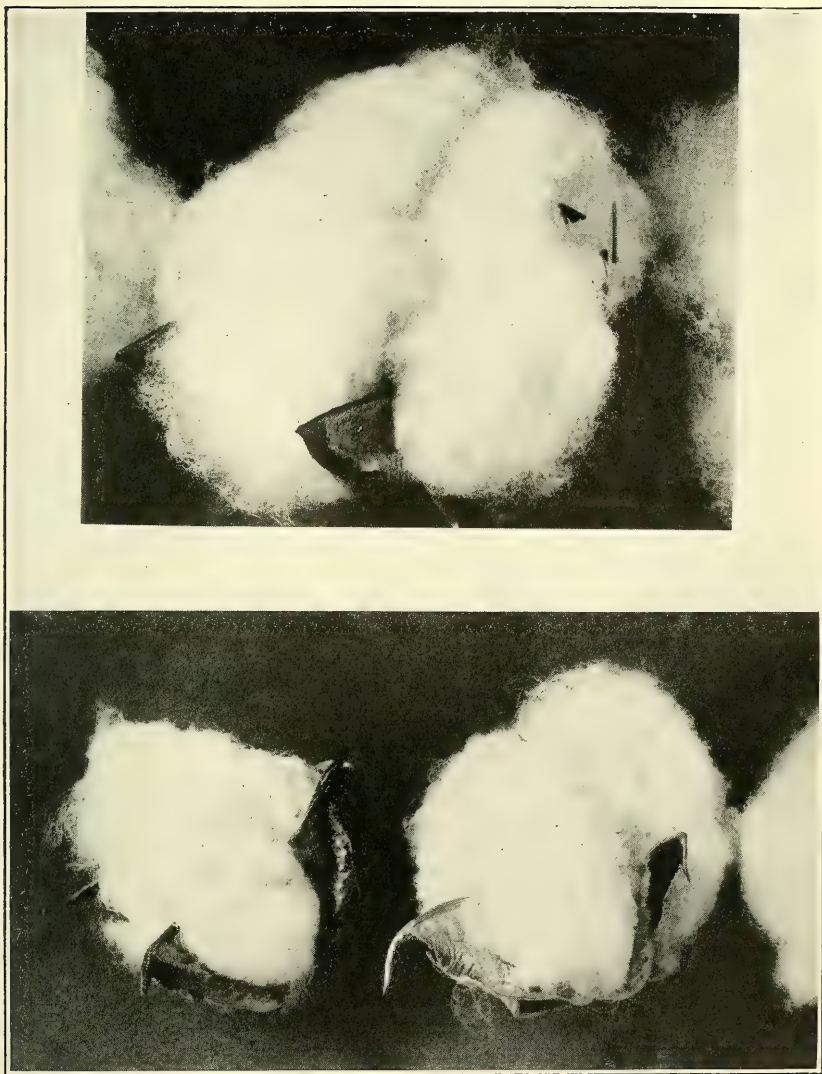
At Statesboro, Ga., the same cooperator who had produced 6 bales of Meade cotton on 8 acres in 1917 produced 42 bales of this cotton from a planting of 46 acres in 1918. This cotton was sold on the Sea Island market at Savannah at a premium over the Sea Island quotations, several of the buyers pronouncing the fiber both stronger and of finer texture than the general Sea Island crop of the season.

Near Sylvester, Ga., nine bales of Meade cotton were produced and sold in the spring of 1919 at a slight premium over the prevailing price for Sea Island cotton of similar grade.

At Cobbtown, Ga., five bales of Meade cotton were produced from a planting of 9 acres. These bales were sent to Savannah along with several bales of Sea Island cotton, the whole shipment being marketed as Sea Island cotton.

On Little Edisto Island, S. C., 5 acres were planted to Meade cotton. The field selected by the cooperator was known to be badly infected with the cotton-wilt fungus and had produced a few years before only 192 pounds of Sea Island lint. While a considerable number of Meade plants were badly affected, a large percentage was vigorous and healthy. Three bales of Meade cotton were harvested from this field and were subsequently sold at a premium of 2 cents per pound over the Sea Island cotton on the Charleston market in March, 1919.

The earliness of the Meade cotton in comparison with the Sea Island was also demonstrated in this planting. The cooperator reported that the entire crop of Meade cotton had been harvested by



MEADE AND SEA ISLAND COTTON BOLLS.

One boll of Meade cotton (top) yields as much as two bolls of Sea Island (bottom). (Natural size.)



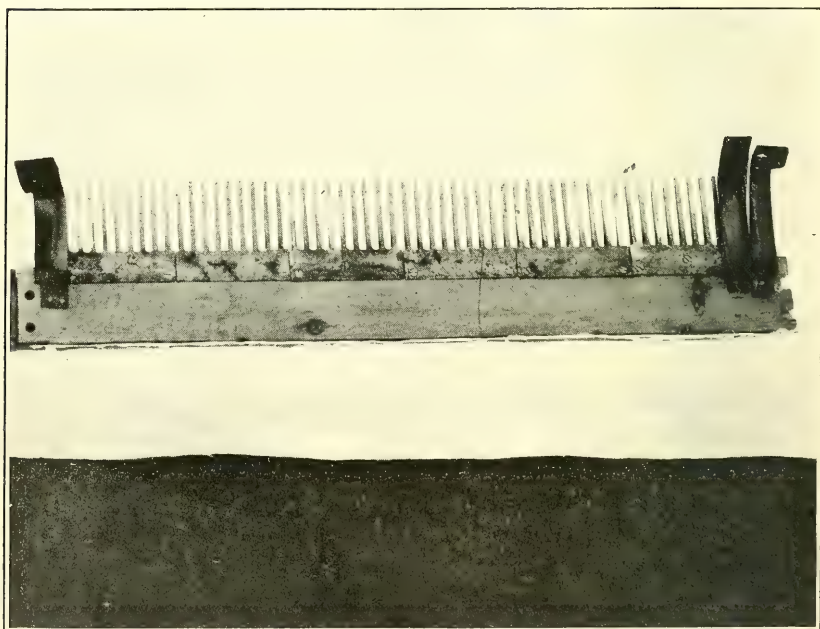
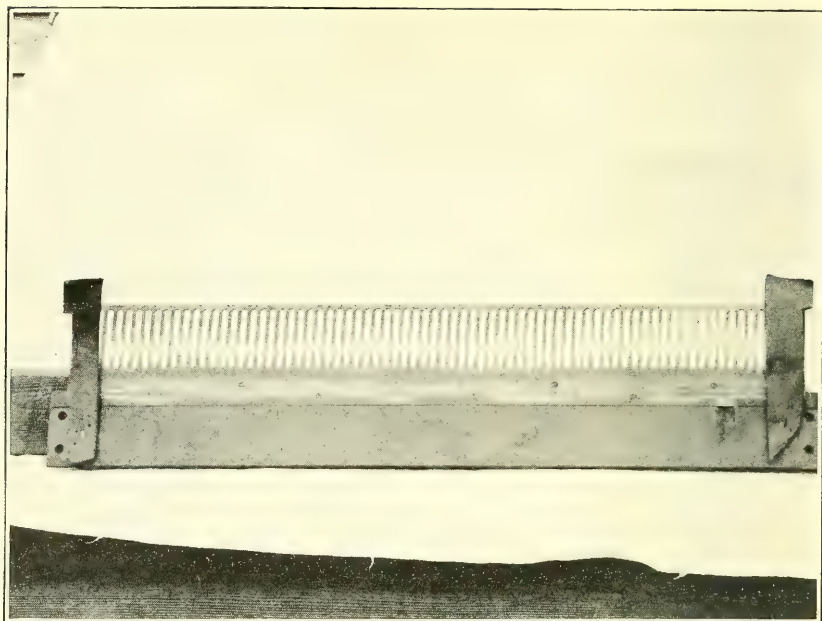
MEADE AND MEADE-SEA ISLAND HYBRID COTTON PLANTS.

A typical Meade plant is shown at the left. The hybrid of Meade and Sea Island shown at the right is undesirable and is to be rogued out of Meade fields. Note the deeply forked leaves of the hybrid, resembling the true Sea Island.



FORMS OF COTTON LEAVES.

Typical Meade leaves are shown at the top, Sea Island leaves at the bottom, and leaves of a hybrid between Meade and Sea Island in the center. The two deeply cleft forms of leaves are to be distinguished from those of Meade cotton in roguing. (Reduced.)



REGULAR SEA ISLAND SEED GRID AND SPECIAL GRID FOR MEADE COTTON.

The seed grid of the regular Sea Island gin is shown in the upper figure. The new grid without bar at the tips of the fingers and a wider space between them to allow the passage of large-sized Meade seed is represented by the lower figure. Setting the regular grid back from the hacker bar three-quarters of an inch also permits Meade seed to pass through without difficulty.

the first of November, while less than 70 per cent of his Sea Island crop had matured at that date.

EXPERIMENTS WITH MEADE COTTON IN 1917 AND 1918.

During the 1918 season additional data were acquired on the relative earliness of the Meade compared with other varieties that showed this cotton to be not only much earlier than the Sea Island, but as early as any of the short-staple varieties now being grown in the Southeastern States.

At the Bureau of Entomology station near Madison, Fla., in a district of heavy weevil infestation, tests were conducted under the direction of Mr. G. D. Smith with several varieties of cotton, including the Meade, King, Express, Webber, and others, besides several strains of Sea Island cotton that had been bred especially for earliness. Flower counts were made daily from June 11, the date of the first flower which appeared on that day in both the Meade and King rows, until August 5, when flowering had practically ceased on all varieties.

The results showed that the Meade variety was as early in producing flowers as any of the short-staple varieties and much earlier than any of the long staples, including the early Sea Island strains. Mr. Smith also reported high yields for the Meade and superiority in both length and abundance of fiber over all the long staples, including the special Sea Island strains.

At Brooksville, Fla., a count was made of the flowers produced each day from June 24 to July 3 on eight rows of Sea Island and eight rows of Meade, each 150 feet long. The Sea Island rows averaged 78.7 flowers and the Meade 153.3 flowers per row per day. The Sea Island yielded 10.3 pounds of seed cotton and the Meade 28.3 pounds per row.

Prof. Loy E. Rast, of the Georgia State College of Agriculture, obtained some very interesting data in 1917 and 1918 on the comparative yields of Sea Island and Meade cotton (9). A review of the more important data reported by Prof. Rast may be summarized as follows:

The Meade cotton was planted along with 37 other varieties at the station in 1917 and ranked No. 1 when the total value of both seed and lint were considered, on a basis of 2,039 pounds of seed cotton per acre, or 693 pounds of lint, worth \$509.35, and 1,346 pounds of seed, containing 24.27 per cent of oil, making it worth \$84.34 per ton, or \$56.76 for the seed produced. The total value of the crop, therefore, was \$566.11 per acre.

A similar test conducted in 1918 by Prof. Rast showed that this variety again ranked first among 38 varieties tested, the total yield of seed cotton being 1,604 pounds, which gave 465 pounds of lint, valued at that time at 70 cents a pound, or \$325.50. The 1,139 pounds of seed contained 23.13 per cent of oil, making it worth \$81.31 per ton, or \$46.30 per acre. The total value of the cotton and seed, therefore, was \$371.80 per acre.

WORK WITH MEADE COTTON IN 1919.

Though adequate supplies of pure seed were not available for general planting in 1919, the stock was sufficient for a wide distribution of small experimental quantities of seed, besides a number of additional larger plantings in other sections of the Sea Island belt.

On account of the failure of many of the Meade cotton growers of 1918 to avoid the contamination of their seed at the gins, it was anticipated that a large quantity of alleged Meade seed that contained a mixture of the Sea Island seed would be sold and planted in 1919. In view of the danger that the reputation for uniformity of the variety might suffer, efforts were made to determine the extent of mixture that actually occurred. Accordingly the names of those farmers who had purchased large quantities of Meade seed were learned, in order that their fields might be inspected.

A visit to a number of these fields in the early season confirmed the suspicion that a mixture of seed had taken place at the gins, for it was found that with only one or two exceptions they contained a large percentage of pure Sea Island plants and practically no hybrids. These farmers were warned that their stock was not pure, that their crop would be a mixture of Sea Island and Meade cotton, and they were advised that, unless all the Sea Island plants were pulled up before flowering, they should dispose of their seed to oil mills at the end of the season.

In striking contrast to these mixed fields was a planting of about 100 acres of Meade cotton near Sylvester, Ga., where the 1918 crop had been ginned on a clean gin. Not a single pure Sea Island plant and not more than a dozen hybrid plants were found in the roguing of the entire acreage. The field was extremely uniform and demonstrated in a most satisfactory manner the possibilities of the variety under conditions of isolation and careful handling.

TABLE 2.—*Yields of Meade and Sea Island cottons in comparable fields of 12 acres each on Little Edisto Island, S. C., in 1919.*

Pickings.	Meade cotton.		Sea Island cotton.	
	Date.	Yield (pounds).	Date.	Yield (pounds).
First picking.....	Aug. 22	302	Aug. 25	190
Second picking.....	Aug. 30	1,040	Sept. 5	607
Third picking.....	Sept. 7	1,253	Sept. 15	733
Fourth picking.....	Sept. 17	1,487	Sept. 29	349
Fifth picking.....	Oct. 7	2,657	Oct. 3	769
Sixth picking.....	Oct. 31	1,200	Oct. 31	100
Total.....		7,939		2,748

On Little Edisto Island, S. C., two fields of cotton, each of 12 acres, were planted. One of the fields was planted to Meade and

the other to Sea Island cotton, and the conditions under which the plantings were made were as nearly alike as possible. The 1919 season was marked by almost continuous rains in this section during July and August, accompanied by a heavy infestation of boll weevils. The yields from these plantings are shown in Table 2.

The relative earliness of the Meade can be seen by a comparison of the yields on the several picking dates.

RESULTS FROM 1919 PLANTINGS.

While something like 3,000 acres had been planted to Meade cotton in 1919, not more than 500 acres had been given the required isolation to prevent possible hybridization with other varieties in adjacent fields. With such a small acreage for the production of pure seed it was evident that the expectations of developing a large supply for the 1920 plantings were not to be realized. It was also expected that from the remaining 2,500 acres of this cotton a large quantity of mixed fiber and seed would appear on the market and that the fiber and the seed as well might be sold as Meade, with further damage to the reputation for uniformity of the variety. To prevent this as far as possible brief statements were issued by the United States Department of Agriculture, summarizing the work that had been done with Meade cotton and advising buyers and manufacturers of the existence of the mixed stocks, so that the variety might not be condemned unjustly if mixed fiber was encountered (10).

While the net results from the 1919 plantings were again disappointing from the standpoint of producing a large increase in the supplies of pure seed, the behavior of the crop continued to demonstrate the practicability of the use of Meade cotton as a substitute for the Sea Island variety under boll-weevil conditions. The problem of replacing Sea Island with Meade cotton was dependent, however, upon the extent of cooperation that could be developed among the farmers and ginners to provide the necessary facilities for producing and maintaining an adequate supply of pure seed.

EXTENDING THE CULTIVATION OF MEADE COTTON IN 1920.

With the supply of pure seed still small, the distribution of small lots for experimental plantings was discontinued in 1920. Seed was sent out only to those localities in the Sea Island belt where good results had already been secured and to responsible farmers who could guarantee isolation for planting and the clean ginning of the crop.

In addition to these precautions, most of the successful co-operators of 1919 agreed to confine as far as possible the sale of their seed to their own immediate locality and to those farmers who could

provide the proper facilities for growing and handling the crop. In this way it was hoped that communities might be organized for growing only the Meade cotton.

STOCKS OF MEADE SEED SCATTERED IN 1920.

The attention that Meade cotton had attracted in Georgia and South Carolina led to numerous inquiries for seed from other sections of the cotton belt, particularly Arkansas and Texas, and in order to ascertain the amount purchased in other sections a list of the names and addresses of farmers to whom Meade seed had been sold and the quantity purchased by each was obtained from the cooperators who had supplies for sale. It was found that while a few of the growers had confined their sales to their own locality, a number had sold seed to farmers in Arkansas and Texas and even to Haiti in the West Indies, where a sufficient quantity had been sent to plant about 2,500 acres.

Numerous plantings of the Meade variety have been made in Texas, Arkansas, Arizona, and California, but the results generally do not encourage growing it in these States on a commercial scale. Favorable local conditions may be found, but Meade cotton, like all other extra long-staple varieties, is subject to injury from drought, such as is likely to occur in either Arkansas or Texas. Drought weakens the fiber and withers the bolls, causing them to split immaturity. Even in favorable seasons it still is necessary to gin the Meade cotton on roller gins, not generally available, and farmers are advised not to attempt to introduce this variety in short-staple Upland districts.

Disregarding such warnings, several hundred bushels of Meade seed were purchased and planted in both Texas and Arkansas. In one county alone in the western part of the latter State about 200 acres were grown.⁴

The absence of roller gins made it certain that the production from these fields would be ginned on a saw gin and probably marketed as Meade cotton. To prevent further damaging criticism of the variety, a warning statement was issued to buyers and manufacturers against the probable appearance on the market of this gin-cut cotton (11).

PLANTINGS IN SOUTH CAROLINA IN 1920.

Although not more than 500 acres of Meade cotton were found to be sufficiently isolated in South Carolina to warrant roguing, more interest in the variety was found among some of the Sea Island cotton growers who had for many years been producing the finest grades of Sea Island fiber.

⁴ It was subsequently ascertained that the crop from these 200 acres was ginned on a saw gin and badly gin cut. While the injury to the fiber was recognized by the farmers, the variety did so well in other respects that 6,000 acres were planted in 1921.

INSPECTION OF MEADE FIELDS IN GEORGIA.

In cooperation with the extension division of the Georgia State College of Agriculture, arrangements were made in the spring of 1920 to inspect all the Meade plantings in Georgia, in order to locate the fields sufficiently isolated from other cotton to warrant roguing and to ascertain approximately the total acreage devoted to this crop in that State.

It was found that while more than 5,000 acres had been planted to Meade cotton, fully half of this acreage had been planted either in the same field with short cotton or so close to other varieties that mixing was certain. The remaining 2,500 acres were well isolated, and with promises of being properly ginned the fields were carefully inspected by either representatives of the State College or of the U. S. Department of Agriculture and the off-type plants removed.

The largest single acreages of Meade cotton were in Worth County, where about 400 acres had been planted on one farm and close to 200 acres on another in the immediate vicinity. Both of these plantings were well isolated, and on account of extreme care in growing this variety through three previous seasons not more than 30 hybrids or off-type plants were removed from both fields. (Pl. VII, figs. 1 and 2.)

ENCOURAGEMENT OF MEADE COTTON IN GEORGIA.

During the 1920 season, a publicity campaign for Meade cotton was carried through by the State and local interests in Georgia (1) that did much to increase the popularity of the variety.

A leaflet entitled "Meade Cotton" (6) was published by the Georgia Breeders' Association⁵, containing 10 brief pointed paragraphs on the origin of the variety and the history of its development in Georgia, as well as information on the comparative merits of the Meade and the Sea Island fiber for spinning purposes. The pamphlet announced that "Meade cotton from a large proportion of the acreage that was planted from pure seed is being concentrated in three warehouses in Georgia, so that spinners may have the advantage of knowing where they can get Meade cotton in quantity."

The following statement from the same leaflet explains the method of tracing impure stocks of seed, in the hope that these inferior stocks might be eliminated:

It is possible that some Meade cotton grown in areas contiguous to short-staple cotton may be of inferior staple and may not be eliminated in the warehouses. If spinners should get bales of mixed or inferior staple they will please notify the warehouse from which the cotton came, or notify the secretary of the Georgia Breeders' Association, at Athens, Ga. This information will be used in checking against impure seed, and standardization will be accomplished the more rapidly.

⁵ The secretary of the Association is R. R. Childs, Athens, Ga.

Under the auspices of the division of agronomy of the Georgia State College⁶ a farmers' meeting was held in Worth County on a farm which had been devoted to the growing of Meade cotton for three successive years. September 9, 1920, was extensively advertised as "Meade Day," and all farmers and others interested in Meade cotton were invited to help inspect the variety growing in the fields and see a demonstration of the value of selection to maintain uniformity and also a demonstration of the proper methods of ginning and baling the crop. (Pl. VIII.) Farmers from all over the State attended, as well as officials of the Georgia State College, the Georgia Breeders' Association, county agents, and representatives of the United States Department of Agriculture.

PRODUCTION OF MEADE COTTON IN 1920.

It has been difficult to obtain accurate data on the total production of Meade cotton for the 1920 season. It is reasonably certain, however, that fully 2,000 bales of this variety were produced, some of which probably has been marketed as Sea Island cotton and is included in the less than 2,000 bales so far reported for that crop.

With very few exceptions the several crops of Meade cotton grown by cooperators have been placed on the market and sold on their own merits as Meade, but a large percentage of the bales produced by other farmers have been offered as Sea Island and have been accepted on the market as such without question. Since the merits of the Meade variety have now been established, however, there appears to be no reason why the cotton should not be marked with its own name.

The United States Department of Agriculture received many requests during the winter and early spring of 1921 for information and for seed of the Meade variety. It is significant that all of the old Meade growers are planting this variety again and increasing their acreage, while a number of new cooperators are growing Meade cotton on a large scale. Among these are several growers who have been for years producing the finest grades of Sea Island cotton. These men know how to maintain the purity and uniformity of a superior cotton and should be able to develop the Meade variety to the same high standard that they reached with the Sea Island.

In order to encourage the community production of Meade cotton the Georgia State authorities selected 10 localities scattered throughout the State in which special efforts would be made to persuade the farmers to grow only Meade cotton in 1921.

⁶ This division has the following staff: J. R. Fain, professor of agronomy; R. R. Childs, in charge of cotton industry; and F. C. Ward, cotton specialist, assisted by E. C. Westbrook.

CULTIVATION OF MEADE COTTON.

There has been a general feeling among farmers that Meade cotton requires some special method of cultivation to secure the best results. No special treatment is necessary for this variety other than that provided for short cotton except that more continuously good growing conditions need to be provided and more care is needed in harvesting and ginning the crop. Failure to provide these conditions affects the length, abundance, and quality of the fiber.

The first essential step to be taken by the farmer intending to grow Meade cotton on a commercial scale is to obtain a good stock of seed. Even at the high price of \$5 to \$6 a bushel good seed is cheap compared to poor seed at \$2 a bushel, because good seed produces larger and more uniform crops of cotton that command a premium on the market, while poor seed yields small crops of mixed fiber which, if detected in the bales, is either unsalable or heavily penalized.⁷

With a stock of good seed the next important consideration is proper isolation for the planting on a well-drained piece of land. If there is any idea of saving the seed to use for planting, the fields should be at least 300 yards distant from any other cotton—the farther away the better. Where a sufficient distance can not be obtained, separation by fields of corn or sorghum may increase the element of safety, since everything depends upon the activity of the insects that visit the flowers. The cotton pollen grains are sticky and are not carried by the wind.

With the proper isolation provided and thorough preparation of the land before planting, from three-fourths of a bushel to a bushel of seed to the acre should be used, depending upon the type of soil, the heavier soils requiring the larger quantity.

The quantity of fertilizer that should be used as well as the proportion of the elements of which it is composed varies in the different localities, but the requirements of Meade cotton will not differ from the local varieties.⁸

The only special requirement for the production of long-staple cotton is that the plants be not forced into overrank growth or checked by drought or other unfavorable conditions. In other words, uniform, equable conditions are required, without extremes on either side to interfere with the gradual, normal development of the crop.

During the growing season the soil about the plants should be kept in good condition by frequent and shallow cultivations. Before flowering time the fields should be carefully inspected in order that

⁷ Either the Georgia State College at Athens or the Federal Department of Agriculture at Washington will be pleased to put farmers in touch with stocks of good seed.

⁸ Each State agricultural experiment station or State college of agriculture is familiar with local conditions and can advise directly regarding fertilizers and the best time for their application.

all hybrids or off-type plants may be removed, to prevent cross-pollination in the field. Later on in the season inferior plants producing off-type bolls may still be found, and these plants also should be removed.

Like all long-staple cottons the Meade variety must be picked with extreme care to keep the fiber as clean as possible.⁹ The seed cotton must be thoroughly and uniformly dried before ginning. There are a number of ways by which this may be accomplished, such as the use of protected platforms, or the lofts of the gin houses, or, if the weather permits, the seed cotton may be spread upon straw mats upon the ground. The cotton must not be more than a few inches in depth and should be turned frequently to allow uniform drying.

It is the belief among farmers that cotton is ready for ginning when the seed cracks between the teeth. Under favorable conditions from two to three weeks should be sufficient, although many of the old Sea Island growers, after thoroughly drying their cotton, store it away until January or February before ginning. By so doing it is claimed that the fiber is given greater luster and strength. Meade cotton must be ginned on a roller gin and the fiber given complete protection in the bale. (Pl. VIII.)

CLOSER SPACING WITH MEADE COTTON.

It has already been demonstrated that profitable crops of Meade cotton can be produced in the presence of the boll weevil and under the usual methods of growing cotton as practiced in the Southeast; but in order to produce the largest possible yields, as well as to induce the plants to set a crop from 10 days to two weeks earlier, the new single-stalk method of culture is being applied to Meade cotton on a farm in southern Georgia.

The new method of culture is based upon the fact that the cotton plant has two kinds of branches, the vegetative branches, usually called "wood limbs" in the Southeastern States, and the fruiting branches that bear the flowers and fruits. The wood limbs are like the central stalk, bearing no bolls directly, the bolls being borne on fruiting branches which are later than those of the main stalk. By chopping the cotton a little later and leaving the plants closer together in the rows the wood limbs are suppressed, thus allowing more plants to stand in the rows without crowding and allowing more fruiting branches to develop and mature an early crop (4). Growers of Meade cotton will be interested in the following summary (12) of the single-stalk method and the results that are being obtained.

Twenty-five to 100 per cent increase in yield is reported by cotton growers who have adopted the new close-spacing system of cotton culture, introduced

⁹ Bales of long-staple cotton containing dirt or trash are more heavily penalized in the market than bales of short cotton.



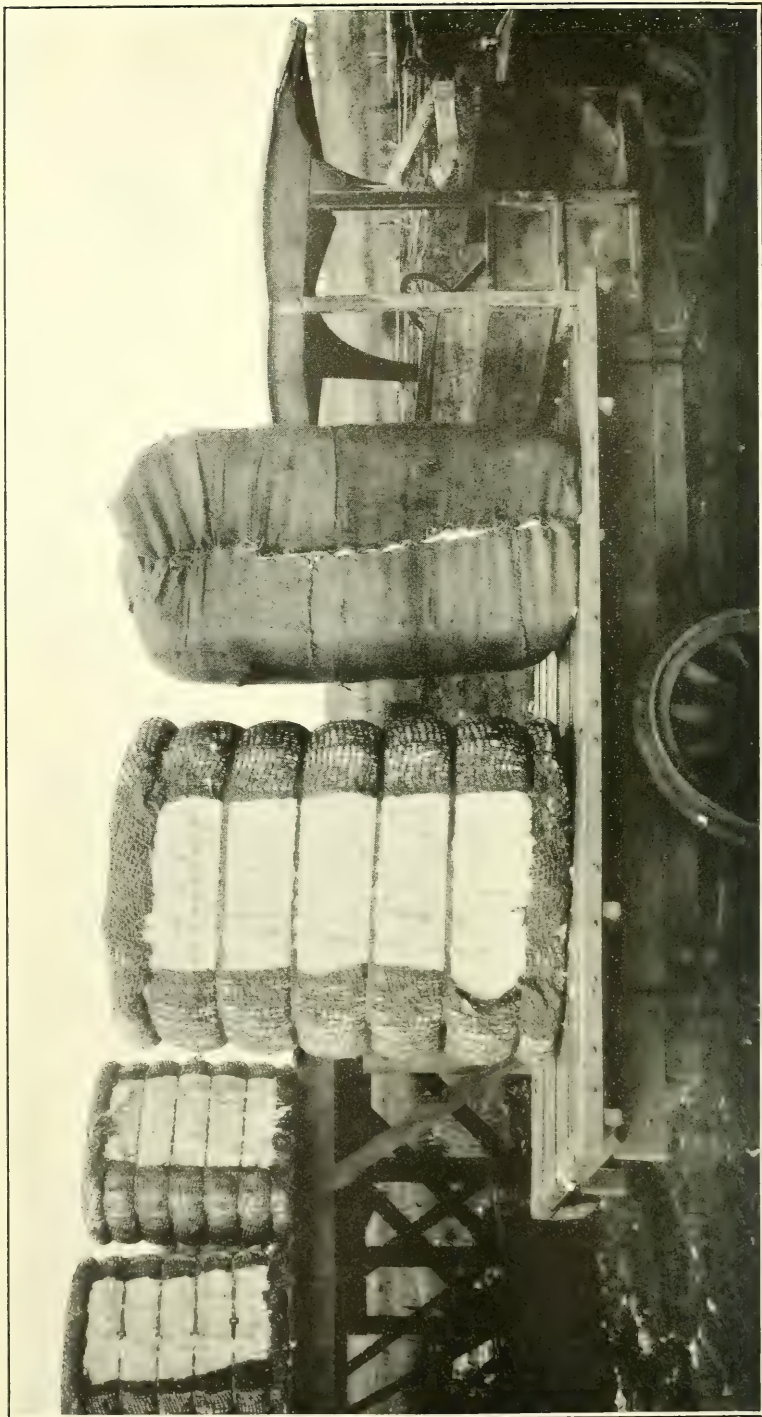
FIG. 1.—IDENTIFYING HYBRIDS AND OFF-TYPE PLANTS.

Plants to be destroyed can be easily distinguished in general field roguing from a slight elevation, as afforded by a horse or mule. A boy can be brought along to pull up the undesirable plants.



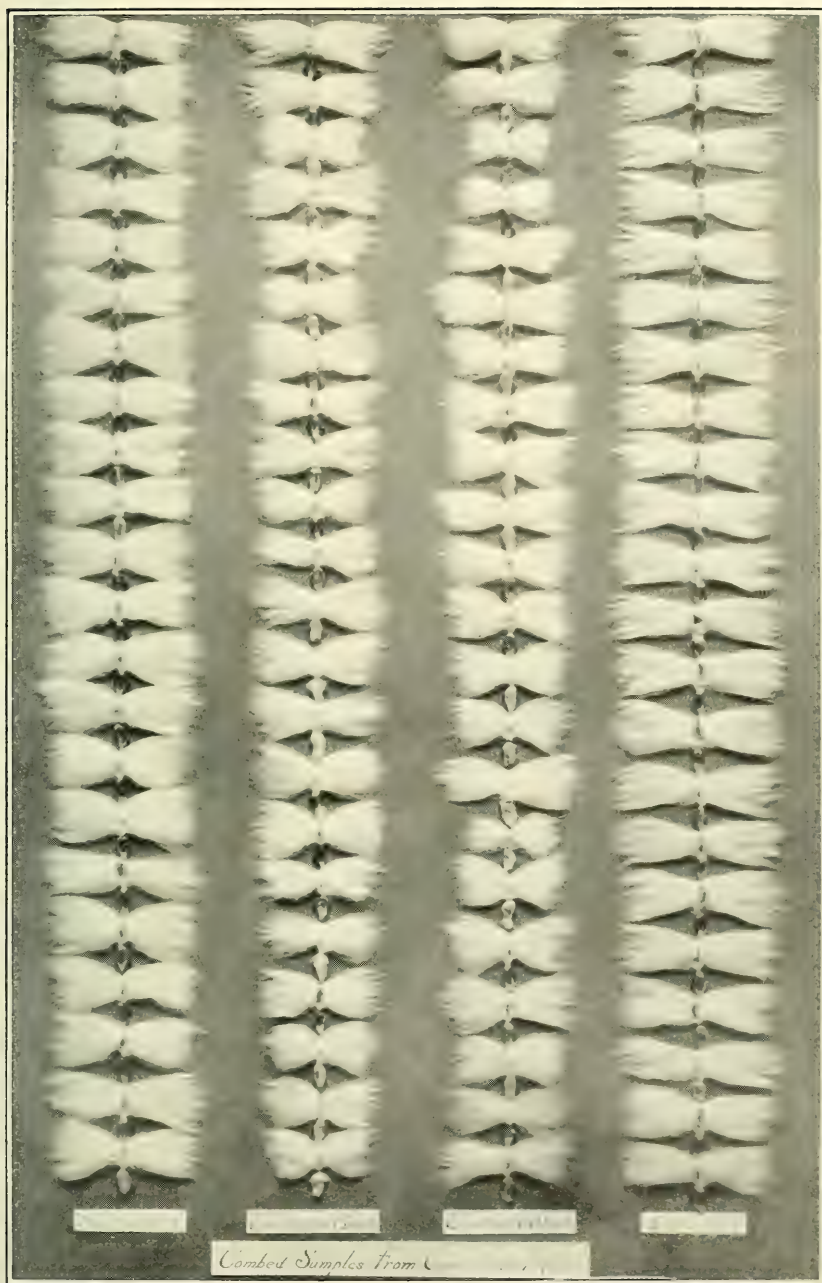
FIG. 2.—MORE INTENSIVE ROGUING OF A SELECTED FIELD OF MEADE COTTON
IN WORTH COUNTY, GA., 1921.

FIELDS OF MEADE COTTON AT THE TIME OF ROGUING.



BALES OF SHORT-STAPLE AND MEADE COTTON.

A bale of Meade cotton (at right) weighing 400 pounds, compared with the usual 500-pound bale of short cotton. The Meade bale is completely covered by strong burlap and sold on sample taken at the gin, thus affording complete protection for the fiber.



SAMPLES OF LINT, SHOWING THE EFFECT OF SELECTION ON THE UNIFORMITY OF MEADE COTTON.

The two center rows show combed lint from consecutive plants in the original unselected stock. The two outside rows show combed lint from consecutive plants in selected stock. Note the uniformity of fiber and seed in the selected stock as compared with the irregularity of both fiber and seed in the unselected stock. (One-fourth natural size.)



8 or 10 years ago by the United States Department of Agriculture. Reports coming directly to the department and to southern agricultural journals which have interested themselves in encouraging the new system show that farmers throughout the cotton regions of the country are rapidly turning to the plan. Increased yield, less labor and expense for the same crop, and a lessening of boll-weevil damage are among the benefits recited in hundreds of letters written by farmers in various parts of the South. Indications are that the system will be adopted far more widely the coming season.

SPACE PLANTS A HOE WIDTH APART.

The close spacing, more commonly known as the single-stalk method of cotton culture, consists primarily in spacing the cotton plants so close in the row—a hoe width apart—that the lower or vegetative branches do not develop, and the growth of the plant goes directly into the upper or fruiting branches, permitting them to begin the development of blossoms and bolls earlier and giving them more nourishment and more light.

The cultural ideal under the new system is a cotton plant with only the single, erect, central stalk bearing numerous well-developed fruiting branches, but none of the vegetative branches or secondary stalks. The suppression of the vegetative branches is easily accomplished by leaving the young plants close together in the rows. Thinning is deferred until the plants are some 6 to 8 inches high, or even later under conditions of rank growth. If the young plants stand less than 6 inches during these early stages of growth, more of them will not produce many vegetative branches, but will have only the upright central stalk and the horizontal fruiting branches.

The distance between the plants is regulated with reference to local conditions and the habit of growth of different varieties, the range being between 6 and 12 inches. The plants then have a narrow upright form and can be left closer together in the rows. Even with the plants only 3 or 4 inches apart in the rows there may be less injurious crowding than with large many-stalked plants 3 feet apart in the rows. The distance between the rows, usually $3\frac{1}{2}$ feet, can also be varied with reference to local conditions, but crowding the rows together so that the sun does not reach the ground is undesirable, especially under weevil conditions.

SMALL PLANTS MAY OUTYIELD LARGE ONES.

In the way of production two distinct advantages are gained: The smaller single-stalked plants, free from any large unproductive offshoots, proceed at once to the development of the branches which produce cotton bolls, and in many cases these small plants produce almost as many bolls and a better quality of lint than large many-stalked plants occupying the space of three of the smaller. The bolls also are produced much earlier on the small plants and are more likely to escape injury by the boll weevil.

The Egyptian cotton industry of the Southwest, which was established as a result of the work of the Department of Agriculture and has added \$20,000,000 a year to the annual agricultural income of the country, could not have been accomplished, in the opinion of department specialists, without the new close-spacing system for controlling the vegetative branches. The benefits to the \$2,000,000,000 cotton crop of the country at large, with continued extension of the new method, can only be faintly estimated.

PROBLEM OF SEED SUPPLY OF MEADE COTTON.

The successful substitution of Meade cotton for Sea Island will depend largely upon the extent of cooperation developed between the farmers and ginners to establish and maintain a supply of pure seed. The purity of a stock can not be maintained if more than one variety is grown in the same or in an adjacent field, for hybridization by insects that visit the flowers is sure to follow. The failure of the Sea Island growers to appreciate the importance of complete isolation and clean ginning for their cotton has been responsible for the popular idea that varieties are bound to run out and that new seed must be secured every few years. They have failed to appreciate the fact that the growers of fine Sea Island cotton on the islands off the coast of South Carolina, from whom their new supplies of seed were obtained, maintained the purity of their stocks by growing only one variety, selecting their seed for planting each year and ginning their crop on their own private gins. The present flourishing Egyptian cotton industry in Arizona owes its success to an early appreciation of the fact that the purity and high quality of the product could not be maintained if more than one variety of cotton were grown in the same community.

The demand for seed of Meade cotton is becoming increasingly large, and efforts are being made to develop an adequate supply of pure seed as soon as possible. Progress has been slower than was anticipated, however, because of the lack of cooperation between the growers and ginners, resulting from the failure of the farmers to appreciate the necessity for clean ginning and of the ginners to appreciate their responsibility to the community in assisting in the maintenance of pure stocks of seed.

With the decrease of Sea Island cotton production these ginning difficulties are likely to be less serious, but there will still remain the necessity for the constant selection and complete isolation of Meade cotton from which seed for planting is to be obtained. Hybrids between the Sea Island and Meade cottons are easily detected and can be rogued out in the early part of the season, but crosses between the Meade and short cotton can be distinguished only with great difficulty before the fiber and seed can be examined, and then the damage by cross-pollination has already been done.

SELECTION NECESSARY TO MAINTAIN UNIFORMITY.

No matter how well selected the Meade stock may be, continuous selection will be necessary to maintain uniformity in the fiber. In the most carefully selected stocks inferior plants will appear; and if these are permitted to remain in the field, insects that visit the flowers carry the pollen from the bad plants to the good ones, and the seed produced by such plants is generally of inferior quality.

The following paragraphs on seed selection appear in a pamphlet sent out by the United States Department of Agriculture (8) with the distribution of seed:

Unless selection is continued, the value of a variety is sure to decline. A well-bred variety is superior to ordinary unselected cotton not only in having better plants, but in having the plants more nearly alike. Whether selection has any power to make better plants is a question, but there can be no doubt of the power of selection to keep the plants alike. Even in the best and most carefully selected stocks inferior plants will appear, and if these are allowed to multiply and cross with the others the stock is sure to deteriorate. The pollen from the flowers of inferior plants is carried about by bees and other insects, and the seeds developed from such pollen transmit the characters of the inferior parent. Even if they do not come into expression in the first generation they are likely to appear in the second generation.

To grow cotton from unselected seed involves the same kind of losses as in an orchard planted with unselected seedling apple trees. Less cotton is produced and the quality is also inferior. The higher the quality of the cotton the more stringent is the requirement of a uniform staple. Unless the fibers have the same length and strength they can not be spun into fine threads or woven into strong fabrics. (Pl. IX.)

PRESERVATION OF VARIETIES BY SELECTION.

The method of selection to be followed in preserving a variety from deterioration is entirely different from that employed in the development of new varieties. The breeder of new varieties seeks for exceptional individuals and prefers those that are unlike any variety previously known. If the selection is being carried on to preserve a variety, the object is not to secure seed from the peculiar plants, but to reject all that deviate from the characters of the variety. The first qualification for such selection is a familiarity with the habits of growth and other characters of the variety, to enable the farmer or breeder to confine his selection to the plants that adhere to the form or type of the variety and to reject all that vary from the type. Most of the latter would prove to be very inferior and at the same time would increase the diversity of the variety and hasten its degeneration.

IMPROVED METHODS OF FIELD SELECTION.

No matter how good a new variety may be or how carefully it may have been bred and selected, inferior plants are likely to appear, especially when it is grown under new and unaccustomed conditions. A special effort is being made to limit the distribution to seed from uniform fields of cotton, but selection is necessary to keep any variety from deterioration, and it is inadvisable to wait until the deterioration becomes serious before beginning the selection. If proper attention be paid to the roguing out of inferior plants in the first season there may be much less variation in the second, the variety becoming better adjusted to the new conditions.

As uniformity is one of the first essentials of value in a variety, the behavior of a new variety in this respect is one of the first things to be noted. Do not wait till the crop matures, but watch the plants in the early part of the season. Even before the time of flowering it is possible to distinguish "freak" plants by differences in their habits of growth or the characters of their stems and leaves. Whenever such variations can be detected the plants should be pulled out at once in order to prevent the crossing of the good plants with infe-

rior pollen. After the bolls begin to reach mature size it is well to go through the plat again and pull out all plants that show by the small size or other peculiarities of the bolls that there has been a variation from the standards of the variety. These preliminary selections greatly simplify the final selection in the fall, when attention can be limited to the yield and to the characters of the lint and seeds (2, 3). (Pls. X and XI.)

USE OF PROGENY ROWS IN SELECTION.

Selection can be made still more efficient by the use of progeny rows. The seed of select individual plants is picked separately into paper bags and planted the next season in adjacent rows, in order to test the behavior of the progenies of the different individuals. An inferior progeny can be rejected as a whole and selection limited to the best rows. It often happens that a very good plant produces a comparatively inferior progeny, which would not be excluded from the stock unless the progeny-row test were made.

Nevertheless, the use of progeny rows is no substitute for skill and care in making the selection, for if the selected plants are not all of the true type of the variety, admixture by cross-pollination will occur in the progeny rows the same as in a mixed planting. Protection against the danger of crossing between different progenies can be secured by holding over a part of the seed of the select individuals used to plant the progeny rows. The remainder of the seed that produced the best progeny row can be planted in an isolated breeding plat in the year following the progeny test. In this way a special strain is developed from a single superior plant.

SPINNING TESTS OF MEADE COTTON.

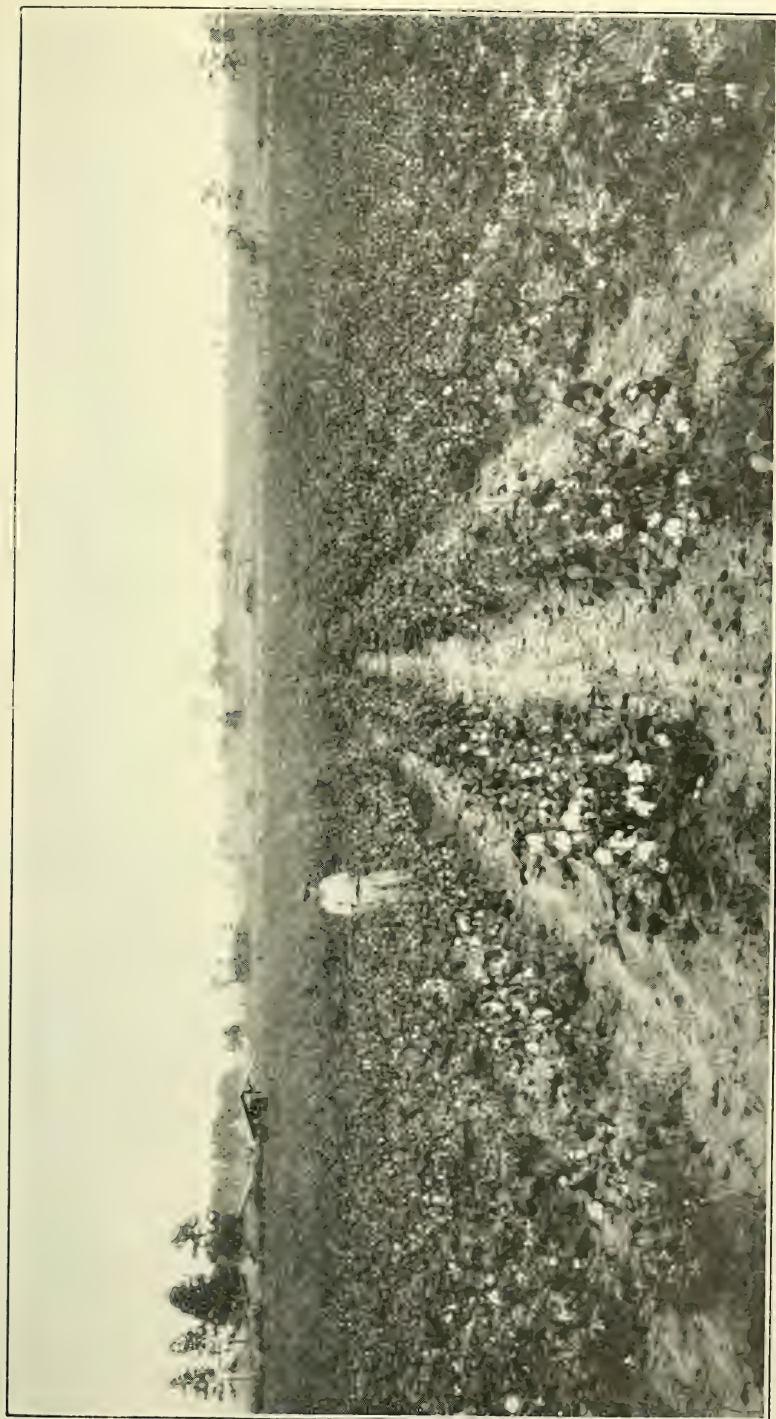
That interest in the new Meade variety was being manifested by New England manufacturers was shown by the purchase of several bales of this fiber in 1918 for the purpose of conducting comparative spinning tests with the Sea Island and Egyptian cottons. The results of one of these tests comparing the Meade and the Egyptian Sakellari-dis cottons are shown in Table 3.

Commenting on the general merits of the variety, the officers of the company making the tests reported in Table 3 state:

The Meade cotton ran equally as well in all processes, and the only material difference was the lessening of twist in the speed frames to an extent of 20 per cent. We consider the Meade to be a very desirable cotton and would suggest the encouragement of its growth on as large a scale as possible.

Comparative tests of Sea Island and Meade cotton conducted by the Bureau of Markets were summarized in the annual report of that bureau for the fiscal year ended June 30, 1920 (13, p. 20-21).

These spinning tests were conducted at the New Bedford Textile School and consisted in spinning the various cottons into different numbers of yarns to determine the comparative waste content of the cotton and the tensile strength of the yarn. The tensile-strength tests were made in the cotton-testing laboratory in Washington, D. C., under 65 per cent relative humidity.



MEADE COTTON IN GEORGIA FROM SELECTED SEED.

An isolated field of Meade cotton from selected seed at Alreda, near Sylvester, Ga., grown to increase the stock of good seed and for further selection.



VARIANT FORMS OF MEADE COTTON PLANTS.

A typical open plant is shown at the left, and an undesirable semiclust plant at the right. The desirable type of Meade plant is of open growth with rather long jointed fruiting branches having 15 to 20 bolls. Many of the undesirable plants are short jointed or "semiclust," often bearing good crops, but usually producing short fiber and fuzzy or "tight" seeds.

TABLE 3.—Results of comparative spinning tests of Meade and Egyptian Sakel-laridis cottons in 1918.

Items of comparison.	Extra fine Sakel-laridis, size No. 120.	Meade, size No. 120.	Good Sakel-laridis, size No. 100.	Meade, size No. 100.
Loss:				
Scutching.....per cent..	3.00	4.96	3.50	4.96
Carding.....do.....	6.00	6.50	6.50	6.50
Combing.....do.....	21.50	21.50	21.50	21.50
Total.....do.....	30.50	32.96	31.50	32.96
Strength.....pounds..	15.90	15.50	18.58	18.50
Yarn counts.....	116.50	116.50	97.50	97.50

The Sea Island and Meade tests were conducted in cooperation with the Bureau of Plant Industry to determine the advisability of urging farmers to plant the Meade variety instead of the Sea Island. The results of the waste tests gave the Sea Island cotton 21.9 per cent and the Meade 26.6 per cent. The results of the tensile-strength tests on these cottons are given in Table 4.

These tests were conducted during the fiscal year 1918-19 to determine the relative value from the spinner's point of view of Sea Island and Meade cottons in the manufacture of airplane fabric. Both of these cottons were $1\frac{5}{8}$ inches in length of staple and about equal in grade. The result of this test indicated that Sea Island cotton was about 5 per cent less wasty than the Meade and from 8 to 20 per cent stronger, depending upon the number of yarn spun.¹⁰

TABLE 4.—Breaking strength of Sea Island and Meade cottons in pounds per skein of 120 yards.

Size of yarn.	Sea Island (fancy, $1\frac{5}{8}$ inches) twist factor.			Meade (S. G. M., $1\frac{5}{8}$ inches) twist factor.		
	3.25	3.50	3.80	3.25	3.50	3.80
No. 100.....pounds..	17.78	17.60	17.18	16.18	16.33	16.00
No. 80.....do.....	25.71	25.91	25.52	24.43	24.09	23.20
No. 60.....do.....	39.90	39.40	38.78	35.77	35.38	34.92
No. 40.....do.....	69.50	69.75	68.48	58.74	60.09	56.93
No. 28.....do.....	128.7	128.0	122.2	108.4	109.2	103.3

¹⁰ Mr. D. E. Earle, then specialist in cotton classing, Bureau of Markets, in charge of these tests, stated that the Sea Island bale used was much superior to the average Georgia Sea Island cotton. In fact, several hundred bales of Sea Island cotton grown in the vicinity of Statesboro, Ga., were examined before one was found of length and grade equal to the Meade. In order to make the test strictly comparable, the two bales were run through all machinery at the same settings, no attempt being made to adjust the machinery to the best advantage for either of the cottons used. But it was found after the test had been made that the Meade comber waste contained considerable long fiber which if it had not been rejected by the comber would have materially reduced the total percentage of waste shown for the variety. This rejection of long fiber by the comber possibly was due to the Meade fibers not being made parallel to the same degree as the Sea Island in the drawing preparatory to the formation of the comber lap. If the Meade fiber had been further drawn before combing, doubtless fewer long fibers would have been rejected and the consequent waste would have been reduced.

During the 1920 season additional spinning tests were conducted by the United States Department of Agriculture, through the cotton-testing specialists of the Bureau of Markets, on representative bales of Meade and Sea Island cottons.

The results of these tests were published in Bulletin 946 (7) entitled "Comparative spinning tests of Meade and Sea Island cottons,"¹¹ from which the data in Table 5 have been taken.

TABLE 5.—Percentages of waste obtained and breaking strength of various sizes of yarns spun from Meade and Sea Island cottons grown in different seasons.

	1916-17		1918-19		1919-20		
Items of comparison.	Meade.	Sea Island.	Meade.	Sea Island.	Meade.		Sea Island.
					Sandy soil.	Clay soil.	
Visible waste:							
Pickers <i>a</i>.....per cent..	1.80	1.04	1.63	1.63	2.34	3.14	1.05
Cards <i>a</i>.....do.....	7.66	7.04	5.70	5.32	6.49	10.01	5.03
Combers <i>a</i>.....do.....	22.45	23.26	19.39	15.03	18.85	16.12	15.20
Total visible <i>b</i>.....do.....	29.48	29.34	24.82	20.55	25.51	26.10	19.79
Invisible waste <i>b</i>.....do.....	.74	.27	2.12	.74	2.54	3.97	3.63
Total visible and invisible waste from pickers, cards, and combers <i>b</i> per cent.	30.22	29.61	26.94	21.29	28.05	30.16	23.42
Size of yarn (3.50 twist multiplier used):							
No. 10.....poundsc.			60.1	69.8			
No. 23.....do.....	129.7	144.7	109.2	128.7	103.8	107.69	122.6
No. 40.....do.....					54.6	53.5	58.5
No. 60.....do.....			35.4	39.4	33.7	30.7	34.8
No. 80.....do.....			24.1	25.9	22.6	19.6	22.3
No. 100.....do.....	15.2	17.4	16.3	17.6	15.5	12.8	15.6

a Based on the net weight fed to the respective machines.

b Based on the net weight fed to the opener picker.

c Per skein of 120 yards.

The results of these tests are summarized in the bulletin cited, as follows:

The grade and staple of the Meade and Sea Island cottons tested were practically equal for the seasons of 1916-17 and 1918-19, but were unavoidably different for the season of 1919-20.

The cotton was run under as nearly identical conditions as possible.

Averaging the visible waste for the three seasons, it was found that the Meade cotton was 3.50 per cent more wasty than the Sea Island.

Comparing the breaking strength of the Meade and Sea Island yarns for the three seasons, a difference of 17.2 pounds was found in favor of the Sea Island for the 23's yarn and 1.68 pounds for the 100's yarn. Under the adverse weather conditions during the growing season of 1919-20, the breaking strength of the sandy-soil Meade was equal to that of the Sea Island for the finer numbers of yarn.

CONCLUSIONS.

Experiments with Meade cotton through several years under a variety of soil and climatic conditions in the Sea Island belt have demonstrated that this variety can be substituted for Sea Island

¹¹ Copies of this bulletin may be obtained without cost upon application to the United States Department of Agriculture.

without disturbing the conditions under which that cotton was produced and marketed.

The harvesting and ginning of Meade cotton should be done with the same care and in the same manner as for Sea Island cotton if comparable returns are to be expected. When so harvested and ginned the Meade cotton causes no change in the customs of the Sea Island markets and is readily accepted on a par with Sea Island cotton.

So closely does the Meade fiber resemble the Sea Island that it can not be distinguished except by experts, and it has been sold on the regular Sea Island markets at a premium over the Sea Island fiber.

Profitable crops of Meade cotton have been produced in the presence of the boll weevil, and comparative experiments indicate that this new long-staple variety is as early and as prolific as the short-staple cottons that are now being grown in the South Atlantic coast districts.

Some difficulty has been experienced with the ginning of Meade cotton because of the failure of the large seeds of this variety to pass through the seed grids of the Sea Island gins as rapidly as the Sea Island seeds, consequently slowing down the ginning process. To meet this difficulty a new seed grid has been manufactured and placed on the market, designed especially to handle the large Meade seeds. This grid can be adjusted to the regular Sea Island gins. It is also possible to use the old grids successfully by moving them back from the hacker bar one-half to three-fourths of an inch.

The production and maintenance of an adequate supply of pure seed is the most acute problem confronting the growers of Meade cotton at this time. Communities of farmers are being encouraged to organize for the purpose of growing only Meade cotton and to keep up the standard of the variety by continued selection and careful ginning on a locally controlled gin. Such organizations can market their crops more directly in large lots of uniform fiber, and better prices can be obtained. Communities organized to grow Meade cotton are more necessary than with Sea Island because Upland hybrids can be easily recognized in Sea Island cotton while Upland hybrids in Meade cotton are difficult to distinguish, so that the precaution of isolating the fields from any possible contamination with short cotton is even more important than when the Sea Island cotton was grown.

The only other solution of the problem seems to lie along the lines that have been followed for years in connection with the Sea Island industry; that is, a few of the more intelligent farmers with private ginning equipment must produce sufficient seed to supply the whole section. Until the organization of communities is effected the latter method seems to offer the better prospects of success, for several of the larger growers of Meade cotton have already installed or intend to install complete ginning equipment for the exclusive handling of this variety.

Spinning and manufacturing tests of the Meade fiber in comparison with both the Sea Island and Egyptian cottons have shown that the difference between these fibers, especially in the finer yarns, is so slight as to be practically negligible.

Although the percentage of waste for Meade fiber is somewhat higher with the same organization of the spinning machinery, such waste may be reduced, if not avoided altogether, by slight changes of adjustment that would be made for the regular spinning of Meade cotton.

LITERATURE CITED.

- (1) ANONYMOUS.
1920. Experts inspect test growing of Meade Cotton. *In* Albany (Ga.) Herald, v. 29, no. 170, p. 3.
- (2) COOK, O. F.
1909. Local adjustment of cotton varieties. U. S. Dept. Agr., Bur. Plant Indus. Bul. 159, 75 p.
- (3) 1910. Cotton selection on the farm by the characters of the stalks, leaves, and bolls. U. S. Dept. Agr., Bur. Plant Indus. Circ. 66, 23 p.
- (4) 1914. Single-stalk cotton culture. U. S. Dept. Agr., Bur. Plant Indus. [Misc. Pub.] 1130, 11 p., 12 fig.
- (5) 1918. Meade cotton. *In* Science, n. s., v. 48, no. 1227, p. 11-12.
- (6) GEORGIA BREEDERS' ASSOCIATION.
[1920]. "Meade" cotton. 4 p., 1 fig.
- (7) MEADOWS, WILLIAM R., and BLAIR, W. G.
1921. Comparative spinning tests of Meade and Sea Island cottons. U. S. Dept. Agr. Bul. 946, 5 p.
- (8) OAKLEY, R. A.
1920. Distribution of cotton seed in 1921. U. S. Dept. Agr. Circ. 151, 16 p.
- (9) RAST, LOY E.
1918. Meade cotton. Ga. State Col. Agr. Circ. 80, 8 p., 5 fig.
- (10) U. S. DEPARTMENT OF AGRICULTURE.
1919. Develops good substitute for Sea Island cotton. *In* U. S. Dept. Agr. Weekly News Letter, v. 7, no. 12, p. 4.
- (11) 1920. Meade cotton should be roller ginned—Fear saw ginning may hurt reputation. *In* U. S. Dept. Agr. Weekly News Letter, v. 8, no. 5, p. 6.
- (12) 1921. Single-stalk method of cotton culture gains favor. *In* U. S. Dept. Agr. Weekly News Letter, v. 8, no. 43, p. 1, 8.
- (13) ——— BUREAU OF MARKETS.
1920. Report of the Chief of the Bureau of Markets, 1919/20. 37 p. Washington, D. C.
- (14) ——— BUREAU OF PLANT INDUSTRY.
1918-1920. Report of the Chief, 1917/18-1919/20. Washington, D. C.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1031

Contribution from the Forest Service
WILLIAM B. GREELEY, Forester



Washington, D. C.

May 15, 1922

RANGE AND CATTLE MANAGEMENT DURING DROUGHT.

By JAMES T. JARDINE, *Inspector of Grazing*, and CLARENCE L. FORSLING, *Grazing Examiner*.

CONTENTS.

	Page.		Page.
The problem of drought and cattle production.....	1	Adjustments necessary, etc.—Contd.	
Jornada Range Reserve.....	4	Breeding herd should be limited to grazing capacity of the range during drought.....	43
Types of vegetation.....	5	Surplus stock should vary with range forage production and with the market.....	46
Use of the area prior to reservation.....	10	Range management to obtain maximum forage production and proper use.....	49
Recurrence of drought.....	11	Improvements necessary to meet increase in cost of cattle production.....	53
Variation in forage production.....	18	Improvements in grade of stock.....	54
Variation due to drought.....	19	Increasing calf crop.....	58
Variation due to grazing.....	25	Decreasing losses of cattle.....	65
Forage production conclusions.....	33	Increasing growth of young stock.....	77
Grazing capacity.....	34	Summary.....	79
Yearlong or winter range.....	35		
Summer range.....	40		
Adjustments necessary in cattle management.....	41		
Southern New Mexico a cattle-breeding section.....	42		

THE PROBLEM OF DROUGHT AND CATTLE PRODUCTION.

Cattle production on ranges of the Southwest in the past has been a business of "ups and downs," with prosperity or adversity governed by climatic conditions, which brought seasons of plenty in range forage and stock water followed by seasons of restricted forage growth and scarcity of water.

Soon after the cattle business became established on the open public range of the Southwest the herds were built up during a period of good years until the developed ranges were stocked fully or beyond the number that they could carry even in good years. Then, at in-

tervals, came dry periods, series of dry years, with much less forage produced than was required by the stock on the range and with heavy losses from starvation. During the early days, before all the ranges had been opened up, there was opportunity to develop new range in such an emergency and thus relieve the situation to some extent. Such possibilities diminished more and more, however, as practically all the range came into use, until there was little opportunity of this nature during the drought that ended in 1910, and practically none in the drought of 1916 to 1918.

The setback to the live-stock industry, caused by this combination of unfavorable climatic conditions and unwise range practice, comes about mainly through heavy losses of stock, low calf crop, interference with improvement of breeding herds, retarded growth of young stock, and range deterioration.

During the last drought, 1916 to 1918, according to estimates based on the best data obtainable, losses were at an average rate of 20 per cent annually for the three-year period and reached as high as 35 per cent in 1918, the worst year of the drought. Individual losses were as high as 50 per cent.

The large reduction in calf crop is probably next in importance to losses. The natural increase is the main source of income, and if greatly reduced at a time when expenses are high the result is serious. The calf crop for some of the ranges affected by the last drought was estimated at 35 per cent in 1917, 25 per cent in 1918, and 35 per cent in 1919, the three years most influenced by the drought. These figures are probably not far from representing the true situation.

Drought also has been a prime factor in retarding improvement in the grade of stock. Heavy losses and forced sales might wipe out years of effort in building up the herd or reduce the numbers to an extent that culling and selection necessary to maintain quality would not be consistent with the importance of increasing the herd to take advantage of good years, or the set-back might be such that it left the stockman financially unable to purchase the right kind of bulls.

Retarded growth and development of young stock is a consequence of the poor forage on the range in time of drought. This results in further decreased returns from the industry, due to lower prices being paid for stock taken, many steers being rejected by buyers and left on the range when they should have been removed to make as much range available as possible for cows, and heifers being stunted and thus requiring another year's growth before they would breed.

Range deterioration, or actual killing out of a part of the valuable forage plants, is one of the bad effects of drought which requires several good years to overcome. The extent of range deterioration

depends upon the duration of the drought and the manner of grazing. A study on the Jornada Range Reserve in southern New Mexico during the dry years of 1916 to 1918 showed that ungrazed range depreciated approximately 40 per cent as a result of natural conditions alone. The depreciation on grazed areas was according to the grazing. Range grazed heavily throughout the year deteriorated from 62 to 70 per cent in the stand of the best forage plants, while ranges not grazed heavily during the main growing season deteriorated as much as 45 per cent.

Many of the best ranges in the Southwest at the close of the last drought were 75 to 80 per cent below their original carrying capacity and will require several years of light stocking and careful management to restore them to even a reasonable condition as regards their carrying capacity.

If the production of live stock is to continue profitably over the vast area of the southwestern ranges the hazard of drought must be minimized. Ranges must not be allowed to deteriorate as they have in the past because of improvident grazing management, and measures for their restoration after drought must be provided for. The present losses of cattle must be cut down and the calf crops increased to more nearly what they should be. The breeding herds must be safeguarded against sacrifice sale and loss in time of drought, and young stock must be kept growing. The solution of the problem of stabilizing the production and reducing the hazards must take into consideration all these phases, and at the same time be capable of practical application to the every-day needs of the business.

Stockmen of this region realize that existing conditions are unsatisfactory. In a majority of cases, however, they are not in a position to apply the remedy, since they do not own the lands and can not regulate grazing upon them. If an individual stockman reduces his herd to save feed for emergency, the surplus grass tempts some one else to move his stock in and graze it. Supplemental feeding as a remedy is limited because of prohibitive cost.

Live-stock production in the southwest is dependent upon the range forage as the primary source of feed, and any remedy for existing conditions must, therefore, include a more conservative and wiser use of the range. The first requirement is centralized control which will regulate use of the range and prevent overstocking as well as insist upon better management plans for drought periods. Supplemental feeding can then be undertaken as far as good business will permit, and there will be opportunity for improvement of both stock and range.

The need for changes in the management of both range and stock, with adjustment especially to meet the trying conditions during periods of drought, led to the establishment in 1912 of the Jornada

Range Reserve ¹ for a study of the problems involved. Investigations started soon afterwards are still in progress. Preliminary results were published in 1917.² The object of this publication is to present results to date, with special reference to the period of drought in 1916 to 1918, inclusive, and to outline the management and investigations proposed for the reserve in future based upon results and experience for 8 years, beginning in 1912.

JORNADA RANGE RESERVE.

The Jornada Range Reserve is an area of approximately 202,000 acres of typical semidesert range lying in a basin adjacent to the Rio Grande Valley in Dona Ana County, N. Mex., about 50 miles north of the Mexican boundary. The major portion of the area is a flat to slightly rolling plain varying in elevation from about 4,100 to 4,700 feet, with a small mass of igneous mountains, the Dona Anas, at the southwest corner. The eastern portion of the reserve, about one-fourth of the total, includes the western slope of the San Andres Mountains.

The locality is one of the most arid in the Southwest. Records for 57 years, at State College, N. Mex., about 15 miles south of the reserve, show an average annual precipitation of 8.60 inches, with precipitation for individual years as high as 17 inches and as low as 3.50 inches. The main rainy season occurs in July, August, and September, with an average of 4.50 inches during these three months. Temperature as high as 106° is common in summer, with almost continuous high winds, low humidity, and consequently high evaporation.

On the plains and foothills the soil ^{2a} shows an almost entire absence of humus, and there is no change in texture with depth, except such as may be purely geological. The lime content is very high, and a highly limy layer or "caliche" is characteristic. The development of this caliche layer is greatest under sandy or gravelly soils and least under the heavier clay soils.

On the plains light-textured soils, principally redish sand loams, loamy sand, and loose incoherent wind-blown soils predominate. On the rolling plain near the foothills of the mountains, areas of coarse gravelly soils are found, and in the center there are flats of

¹ The Jornada Range Reserve was created by Executive Order May 3, 1912, at the request of the Department of Agriculture, with the idea of securing a complete range unit for conducting experiments and demonstrations in range management under conditions existing in southern New Mexico and similar country in adjoining States. The boundaries were slightly modified by Executive Order Apr. 24, 1916, and at present include about 202,000 acres. Since May 1, 1915, the investigations have been made by the Forest Service of the Department of Agriculture.

² Jardine, James T., and Hurtt, L. C., Increased Cattle Production on Southwestern Ranges, U. S. Dept. Agr. Bull. 588, 1917.

^{2a} Classification of soils on the reserve made by U. S. Bureau of Soils.

compact tight clay or "adobe." There is very little alkali land, except in the adobe lake beds, where water often stands until it evaporates.

The only water originally on the lands now within the reserve consisted of a number of mountain springs and intermittent lakes or flat depressions in the bottom of the valley.³ Water for stock on plains range, both on the reserve and on adjacent range lands, is now pumped from deep wells by windmills and engines or is supplied by pipe lines carrying water from springs in the mountains and by tanks which catch and store flood waters. The reserve is now well watered, watering places for the most part being not more than 5 miles apart.

TYPES OF VEGETATION.

The greater part of the forage, perhaps 80 per cent, is furnished by perennial grasses, of which the most important are black grama, red three-awn or needlegrass, tobosa, dropseed, muhlenbergia, burro-grass, and alkali sacaton or saltgrass. Various brush species, among which mesquite, blackbrush, creosote bush, shadscale, sagebrush, and Mormon tea predominate, are found on the mesa or plain.⁴

Many species of both perennial and annual weeds, as well as various annual or "six-weeks" grass species, occur during the rainy season, but their duration is short and they do not furnish a great amount of forage.⁵

³ The Jornada del Muerto plain, upon which the reserve is located, slopes gently toward a central depression or bolson with no drainage out.

⁴ Black grama=*Bouteloua eriopoda*.

Red three-awn grasses=*Aristida longiseta*, *A. pansa*, *A. purpurea*.

Tobosa grass=*Hilaria mutica*.

Dropseed grass=*Sporobolus cryptandrus*, *S. flexuosus*, *S. wrightii*, *S. auriculatus*.

Ring muhlenbergia=*Muhlenbergia gracillima*.

Bush grass=*Muhlenbergia porteri*.

Alkali sacaton or saltgrass=*Sporobolus airoides*.

Burro-grass=*Scleropogon brevifolius*.

Low tridens=*Tridens pulchellus*.

Mesquite=*Prosopis glandulosa*.

Blackbrush=*Flourensia cernua*.

Creosote bush=*Covillea glutinosa*.

Snakeweed=*Gutierrezia furfuracea*.

Shadscale=*Atriplex canescens*.

Sagebrush=*Artemisia filifolia*.

Mormon tea=*Ephedra torreyana*.

⁵ Some of the most important of these are as follows:

Perennials—

Baileya=*Baileya multiradiata*.

Spurge=*Chamaesyce* spp.

Leatherweed=*Croton corymbulosus*.

Spectacle-pod=*Dithyrea wislizeni*.

Evolvulus=*Evolvulus pilosus*.

Hoffmanseggia=*Hoffmanseggia* spp.

Hymenopappus=*Hymenopappus robustus*.

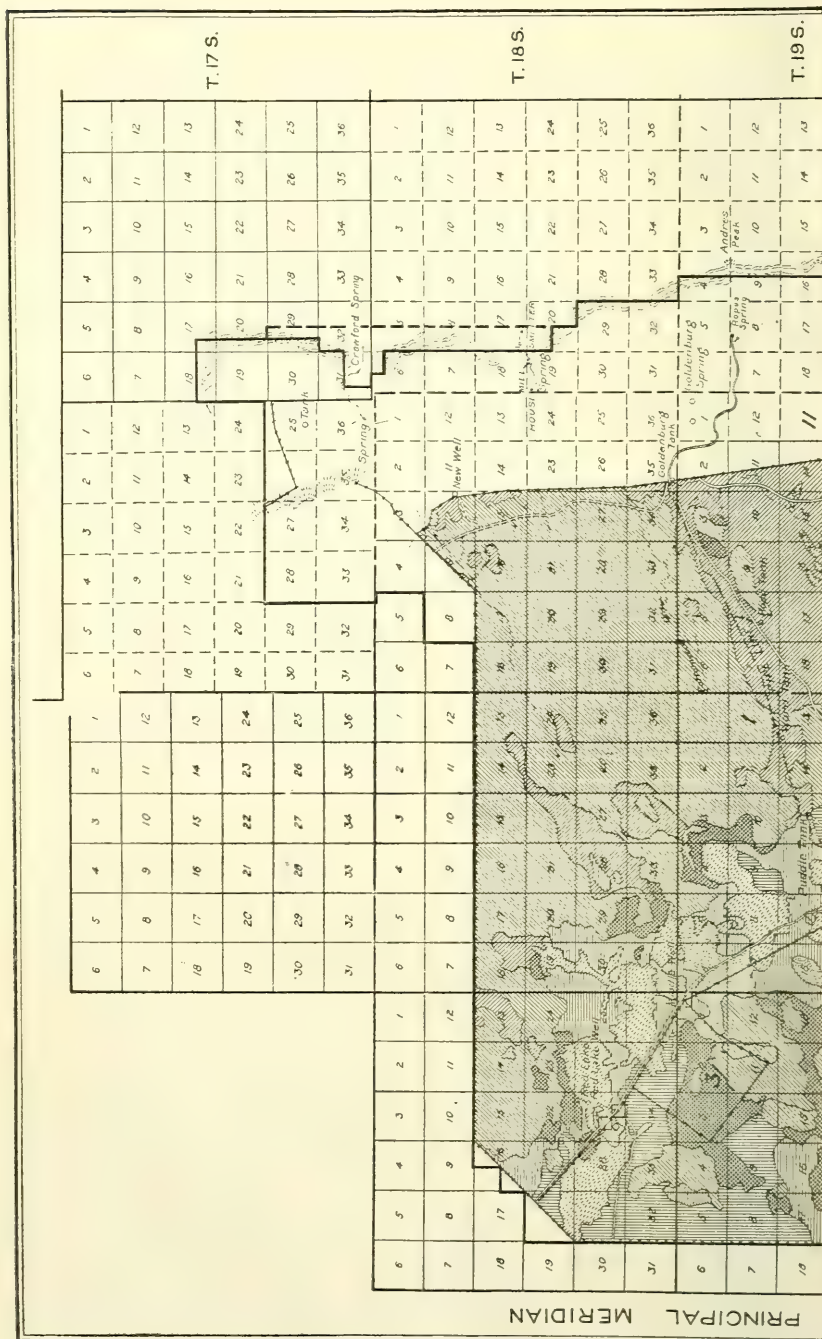
Yellowbush=*Psilostrophe tagetinae*.

Bushy senecio=*Senecio filifolius*.

Silvery nightshade=*Solanum elaeagnifolium*.

Whitestem=*Mentzelia multiflora* (mostly biennial).

(Footnote continued on page 8.)



The vegetation is more or less grouped into types. Figure 1 shows the vegetation classified into these range types for the plains of the reserve. Table 1 gives the acreage of each type by pastures of the reserve.

TABLE 1.—*Acreage by types and pastures of the plains area of the Jornada Range Reserve.*¹

Pasture.	Grama-grass.	Snake-weed.	Mesquite-sandhill.	Sage-brush.	Weed.	Swag.	Mixed grass.	Black-brush—creosote bush.	Total.
1.....	<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>
2.....	3,416	1,438	31,730	8	894	5,393	² 5,472	26,363	74,714
3.....	14,473	4,834	5,922	423	721	1,658	² 6,514	.....	34,545
5.....	541	963	486	50	82	168	² 120	.....	2,410
7.....	1,497	.....	74	.....	461	286	² 497	.....	2,815
8.....	533	.....	.....	.....	.....	.....	² 408	509	1,450
9.....	315	.....	.....	.....	.....	33	² 1,255	2,427	4,030
10.....	.....	.....	.....	.....	.....	138	² 401	245	784
11.....	4,292	260	.....	.....	.....	.....	² 253	.....	4,805
12.....	746	.....	.....	.....	.....	68	² 52	6,183	7,049
13.....	1,538	.....	.....	.....	45	398	² 2,401	12,619	17,001
Total.....	27,351	7,495	38,212	481	2,203	8,142	17,373	48,346	149,603

¹ Pasture No. 11 is not included. This is an area of approximately 52,317 acres of mixed grasses and browse types in the San Andres Mountains.

² Mixed-grass type in this pasture mainly grama, three-awn, and drop-seed grasses.

³ Mixed-grass type in this pasture mainly burro, tobosa, and salt grasses.

Because of the time of the year during which the forage in the various types is palatable to cattle and the growth habits of the main forage species, the several types are divided into yearlong or winter range, and summer range. The grama-grass type, mixed grama, three-awn, and dropseed-grass type, snakeweed type, and mesquite-sandhill type constitute the yearlong or winter range, and the swag type, mixed tobosa, burro, and salt-grass type, and black-brush-creosote bush type make up the summer range.

YEARLONG OR WINTER-RANGE TYPES.

The grama-grass type (Pl. I, fig. 1) is the most important of the several yearlong or winter-range types. Black grama grass is the predominating plant species in this type, but other grasses, such as three-awn and dropseed occur to some extent. Soapweed⁶ is the most conspicuous species next to the grama grass and is nearly always found in this type. Occasionally three-awn and dropseed grasses are more abundant than the grama grass, and in such cases form a mixed-

Footnote continued from page 5:

Annual weeds—

Boerhaavia=*Boerhaavia torreyana*.

Mouse ear=*Tidestromia lanuginosa*.

Eriogonum=*Eriogonum* spp.

Glandleaf=*Pectis angustifolia*.

Caltrops=*Tribulus terrestris*.

Six-weeks grasses—

Aristida bromoides, *Bouteloua aristidoides*, *B. barbata*, *B. parryi*.

⁶ Soapweed=*Yucca elata*.



F-36842-A

FIG. 1.—BLACK GRAMA-GRASS RANGE IN SOUTHERN NEW MEXICO.

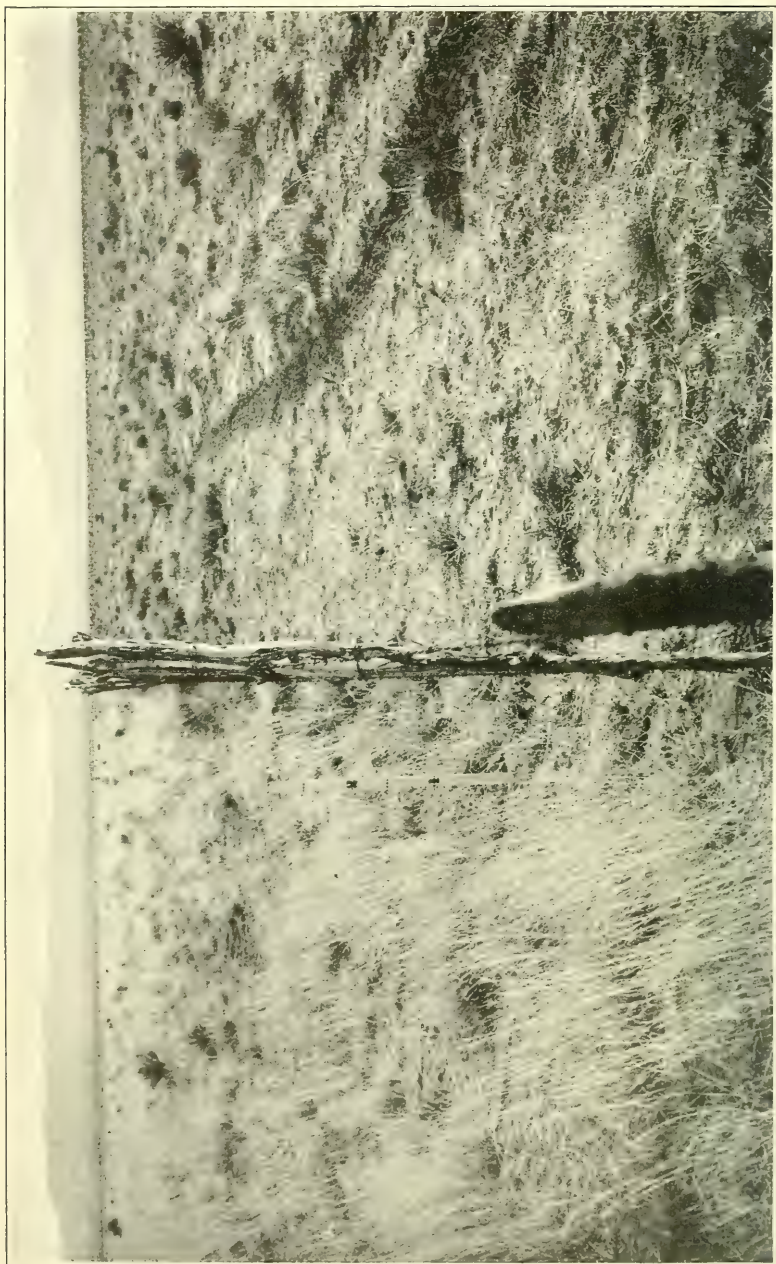
In good years there is abundant feed on this kind of range, but in time of drought the carrying capacity may be reduced as much as 50 per cent or more. Reduction of grazing 30 to 50 per cent of the year-long rate during the growing season is the main requirement for maintenance of grama-grass range.



F-43195-A

FIG. 2.—TOBOSA-GRASS RANGE ON THE JORNADA RANGE RESERVE.

The growth habits, compact soil it occupies, and low forage value after the growing season adapt this type of range to summer grazing. It is not easily killed out but carrying capacity is very low in time of drought.



F-161937

PASTURE 10 (LEFT), AND OUTSIDE RANGE (RIGHT).

Range on left was not grazed until after the growing season each year. That on the right has been heavily grazed yearlong for a number of years; much of the best grass has been killed and worthless weeds, especially snakeweed, are taking its place.

grass type. The grama grass occupies the more compact sandy soils, and this phase of the mixed-grass type the slightly looser soils.

The snakeweed type, although of minor importance, resembles the grama-grass and mixed-grass types in composition of forage plants, with the difference that snakeweed is the predominating species. There are also more weed species in this type, probably because the soil is a little looser than in the two types just discussed. Snake-weed is often an indicator of overgrazing, especially when it comes in on areas of better soil, but it also occupies a natural habitat of its own on the loose soils.

The mesquite-sandhill type has a very low density of palatable vegetation. It occupies more area than any other type on the plains areas of the reserve. Mesquite is the predominating plant species in the type, occurring in clumps which serve to catch blowing sand and thus to form the mounds or small sandhills. Other browse species occurring with the mesquite are shadscale and sagebrush, the sagebrush sometimes predominating on small areas to an extent that a distinct sagebrush type is formed. Both these species of brush are good forage for cattle, especially in winter. Grama grass, red three-awn, and dropseed grasses are the most important grasses found here, and, although they ordinarily occur sparsely, furnish the bulk of the feed in the type. A scattered stand of soapweed is characteristic of this type. Drifting of the soil occurs during high winds, and this makes it difficult for vegetation to become established from seed.

In all four of these types black grama grass is the most important forage species. The three-awn grasses and the various browse species are next in importance. These grasses are good forage when they are green, and they cure on the stalk on the range. The dry forage is readily eaten by stock. The various browse species in the mesquite type are grazed mainly during winter and spring. Consequently the grama-grass type and the other types in which grama grass or browse are the predominating forage species are important for winter and spring grazing, when there is little new growth, and the demand upon them for these seasons should be given first consideration. Also, since grama grass is the principal forage species in all of these types, their management should be based upon the growth requirements of grama grass.

SUMMER RANGE TYPES.

The swag or swale type (Pl. I, fig. 2) occurs on the low flat places of tight soils that are flooded from run-off in time of rains. Tobosa grass and burro grass are the only species of importance in this type.

Bordering on the swag type and on somewhat similar situations is a mixed-grass type in which occur mainly tobosa grass, burro grass, and saltgrass (given in the order of their importance).

The blackbrush-creosote bush type, composed mainly of a stand of these two brush species with an under cover of grass, occupies the level to slightly rolling area where clay to gravelly loam soils predominate. This type varies from the blackbrush phase with an under cover of tobosa grass, burro grass, and saltgrass on the more compact clay soil to the creosote-bush phase with bush grass, grama grass, and low tridens on the drier, more gravelly slopes and ridges. Although the latter are yearlong range grasses, the occurrence of this phase of the blackbrush-creosote bush type is too limited to segregate it from the summer range for grazing.

Tobosa grass is the most important forage plant in the three summer types, since it is the most palatable and abundant of the grasses and the brush species are worthless as forage. Soon after the growing season this grass becomes dry and unpalatable to cattle, and if not grazed before that time most of it is wasted. In fact fairly close grazing of this species is essential during the growing season; otherwise the dead material remaining interferes with utilization of new growth the following year. Close grazing during the growing season does not easily injure tobosa grass because of its underground method of revegetation, the compact soil it occupies, and the rapidity and rankness of its growth. The burro grass begins growth early and has its main value as forage before other vegetation has greened; after that time it is grazed but little. The saltgrass is another early feed, but, like tobosa grass, is of little value after it stops growth. These conditions and the high carrying capacity of the tobosa grass type make these three types ideal for summer grazing in the Southwest.

USE OF THE AREA PRIOR TO RESERVATION.⁷

Prior to 1912 a number of individuals had attempted to develop water in wells and establish ranches on the land now within the reserve. The difficulty and cost of sinking deep wells, the prevalence of droughts, and severe losses discouraged the small owners and their range rights were eventually purchased by a single owner.⁷ This

⁷ The range rights on this area were purchased previous to 1911 by Mr. C. T. Turney, who is cooperating with the Forest Service in carrying on the studies. At the time of the creation of the reserve the 200,000-acre range unit was conceded to Mr. Turney by neighboring stockmen under common or range rights established by the purchase of prior rights and improvements of other owners and the construction of watering places on unused range. He leases all State lands and owns private lands around most of the wells. The Government furnishes the public lands under reservation. The experiments are planned by the Government and the stockman, and carried out according to agreement. All fencing, water development, and other construction work, as well as extra labor in handling stock for experimental purposes, are paid by the cooperator in lieu of grazing fees on the Government land. The Government furnishes the men to keep proper records of all experiments, to aid in the planning of new investigations, and to see that the work is properly conducted. Prior to the coming of Mr. Turney to this part of the county there had been no successful wells put down on the Jornada del Muerto plain except one very shallow well near Aleman, N. Mex. This broad expanse of dry plain even won

owner, who is the cooperator with the Department of Agriculture in the experiments, occupied part of the present area of the Reserve as open range and developed the first substantial permanent wells in the vicinity in 1904. With the exception of slightly better watering facilities due to development of several more wells and tanks on the area than on the average open range of the same size, the area was handled much the same as the average open range prior to the creation of the reserve, May 3, 1912. Stock grazed any part of the range yearlong, there was no provision for drought or to prevent overgrazing, losses and calf crop were about the same as elsewhere, and any attempts to improve the grade of stock were discouraging.

During the drought of 1908-1910 the experiences on the area now included in the reserve were similar to those that occurred on many other open ranges in that drought and in the drought of 1916-1918. Several good years had preceded the drought and in 1908 there were about 5,000 head of cattle on the 200,000 acres. In 1911, when the drought was over, only 600 head of cattle remained. The rest had starved to death or had been moved out to where range forage was available but the expense of returning them was not warranted. This is in contrast to the results presented in this bulletin for the same range under as bad or worse drought conditions, when the area was being handled under methods adjusted in part, at least, to preserve permanence in the industry through drought periods.

RECURRENCE OF DROUGHT.

The effect on the cattle business of the combined factors which together constitute what is generally understood as a "drought" has been outlined. The heavy losses, retarded growth of stock, low calf crop, heavy expense, range depreciation, and worry to the owners during such a period obviously warrant maximum effort to anticipate the recurrence of drought periods and the consequent reduction in range forage production. Records covering a period long enough to do this with certainty are not available, but an analysis of the rainfall and other records at hand and of past experience helps in explaining management later suggested to meet drought conditions.

Precipitation data for two stations—El Paso, Tex., and State College, N. Mex.—From 1886 to 1919, inclusive, except records which are lacking for State College in 1890 and 1891, are given in Table 2.⁸ These data include the annual precipitation and the amount received

the name of Jornada del Muerto (the journey of Death) from the Spaniards in the early days because of the many people who had died of thirst in traveling over the area. It is here that the old Santa Fe trail came out on the plain, leaving the valley of the Rio Grande near Fort Selden because of the narrow, rocky gorge of the river farther north, and ran some 90 miles over the dry plain to a point just south of San Marcial, N. Mex.

⁸ Data from Reports of the U. S. Weather Bureau and Bulletin 113, New Mexico College of Agriculture and Mechanic Arts, Climate in Relation to Crop Adaptation in New Mexico, by Charles E. Linney and Fabian Garcia, 1918.

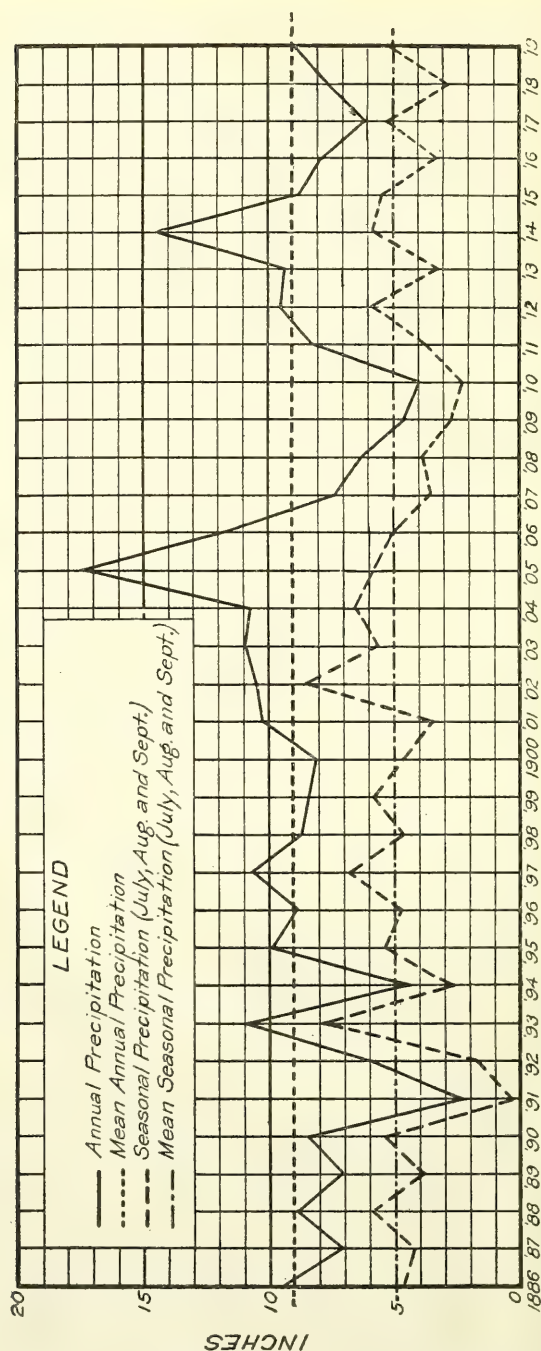


FIG. 2.—Annual and seasonal precipitation, State College, N. Mex., and El Paso, Tex.

during the main growing months—July, August, and September—and the departure above or below average for each year and season. Figure 2 shows these data graphically.

TABLE 2.—Average annual and seasonal (July, August, and September) precipitation for two stations (El Paso, Tex., and State College, N. Mex.), and departures from normal.

Year.	Annual rain-fall. ¹	Departure from average. ²	Seasonal rain-fall. ¹	Departure from average. ²	Year.	Annual rain-fall. ¹	Departure from average. ²	Seasonal rain-fall. ¹	Departure from average. ²
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>		<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
1886.....	9.50	0.48	4.60	0.34	1904.....	10.71	1.69	6.47	1.53
1887.....	7.09	1.93	4.34	.60	1905.....	17.44	8.42	5.88	.94
1888.....	8.94	.08	5.91	.97	1906.....	11.89	2.87	5.13	.19
1889.....	7.08	1.94	3.87	1.07	1907.....	7.41	1.61	3.57	1.37
1890.....	8.49	.53	5.41	.47	1908.....	6.45	2.57	3.98	.96
1891.....	2.22	6.80	3.42	4.52	1909.....	4.63	4.39	2.73	2.21
1892.....	5.92	3.10	1.73	3.21	1910.....	4.02	5.00	2.40	2.54
1893.....	10.80	1.78	7.97	3.03	1911.....	8.34	.68	3.78	1.16
1894.....	4.26	4.66	2.65	2.29	1912.....	9.67	.65	5.96	1.02
1895.....	9.83	.81	5.47	.53	1913.....	9.41	.39	3.28	1.66
1896.....	8.89	.13	4.75	.19	1914.....	14.43	5.41	5.90	.96
1897.....	10.68	1.66	6.87	1.93	1915.....	8.81	.21	5.58	.64
1898.....	8.68	.34	4.65	.29	1916.....	7.97	1.05	3.34	1.60
1899.....	8.48	.54	5.87	.83	1917.....	6.03	2.99	5.23	.29
1900.....	8.17	.85	4.60	.34	1918.....	7.72	1.30	2.95	1.99
1901.....	10.32	1.30	3.52	1.42	1919.....	8.96	.06	5.04	.10
1902.....	10.52	1.50	8.56	3.62					
1903.....	10.96	1.94	5.67	.73	Average.	9.02	.....	4.94	.....

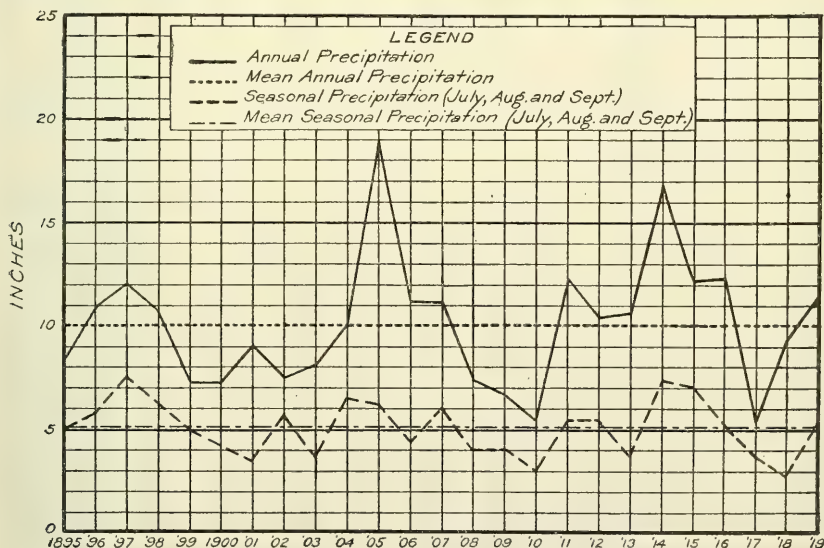
¹ Bold-faced figures represent years below average.² Bold-faced figures for amount below average; other figures for amount above average.³ Data for State College lacking.

FIG. 3.—Annual and seasonal precipitation in southern New Mexico.

Owing to local variation in precipitation, figure 2, based upon records of two stations, represents only the general characteristics of southern New Mexico. Figure 3, based upon 24 years' (1895 to 1919, inclusive) records from seven stations (Table 3), although for a shorter period, covers slightly wider territory and is perhaps more representative of the semidesert ranges in New Mexico.⁹

⁹ Data from Reports of U. S. Weather Bureau and Bulletin No. 113, New Mexico College of Agriculture and Mechanic Arts, Climate in Relation to Crop Adaptation in New Mexico, by Charles E. Linney and Fabian Garcia, 1918.

TABLE 3.—*Annual and seasonal (July, August, and September) precipitation for seven stations in southern New Mexico and vicinity with departure from the normal.*

Year.	Agricultural College.		Alamagordo.		Elephant Butte.		El Paso, Tex.		Lordsburg.	
	An-nual. ¹	Sea-sonal. ¹	An-nual. ¹	Sea-sonal. ¹	An-nual. ¹	Sea-sonal. ¹	An-nual. ¹	Sea-sonal. ¹	An-nual. ¹	Sea-sonal. ¹
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
1895.....	9.47	6.18			9.11	6.47	10.20	4.77	5.44	2.51
1896.....	7.99	4.21			10.84	6.04	9.79	5.30	13.55	5.76
1897.....	8.96	5.55			16.89	10.40	12.41	8.19	13.33	9.70
1898.....	11.21	6.35	19.23	12.60	14.38	8.75	6.16	2.96	6.13	2.63
1899.....	9.67	7.12			7.12	4.27	7.30	4.63	5.73	4.80
1900.....	8.40	4.22			6.03	3.97	7.95	4.99	6.99	4.34
1901.....	11.96	4.83	11.47	3.79	8.49	3.54	8.68	2.21	7.41	3.23
1902.....	10.90	9.15	7.25	5.30	6.19	5.26	10.15	7.98	5.87	3.80
1903.....	10.29	4.90	6.95	3.47	6.76	1.50	11.63	6.44	4.04	2.08
1904.....	10.13	6.62	8.95	4.92		8.80	11.30	6.33	8.07	5.30
1905.....	17.09	6.39	19.25	5.07			17.80	5.37	19.50	5.61
1906.....	8.80	2.97	11.16	3.05			14.99	7.30	9.58	3.49
1907.....	6.42	3.33	10.88	6.41			8.41	3.81	12.15	6.25
1908.....	5.97	3.35	12.11	7.62			6.94	4.62	8.66	3.23
1909.....	4.94	2.74	6.85	3.64	6.68	5.33	4.33	2.73	10.18	7.53
1910.....	4.02	2.79	8.65	5.04	5.79	2.70	4.03	2.02	4.95	2.96
1911.....	5.80	2.68	12.69	5.65	13.51	6.84	10.88	4.88	11.73	3.54
1912.....	9.20	6.22	9.61	5.33	10.95	5.82	10.14	5.71	14.15	6.33
1913.....	11.73	4.30	12.38	3.93	12.27	4.40	7.09	2.27	11.69	2.51
1914.....	11.85	4.48	19.03	7.43	15.12	7.68	17.02	7.32	19.70	7.69
1915.....	7.37	4.67	14.00	8.08	13.87	7.96	10.26	6.50	10.91	4.77
1916.....	7.78	2.47	12.46	5.03	13.73	5.77	7.77	4.21		
1917.....	5.58	4.91	5.20	3.97	3.53	2.85	6.49	5.56	8.28	4.57
1918.....	7.23	2.71	11.47	2.73	10.76	4.95	8.21	3.19		.50
1919.....	8.05	4.20	15.02	7.25	11.64	5.15	9.87	5.89		
Mean.....	⁸ 8.51	⁴ 4.81	⁵ 11.48	⁵ 5.49	⁶ 10.18	⁶ 6.13	⁷ 9.53	⁷ 5.07	⁸ 9.28	⁹ 4.47

Year.	Socorro.		Deming.		Mean annual.		Mean seasonal.	
	An-nual. ¹	Sea-sonal. ¹	An-nual. ¹	Sea-sonal. ¹	Rain-fall. ²	Depart-ure. ³	Rain-fall. ²	Depart-ure. ³
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
1895.....			8.23	5.58	8.49	1.52	5.10	0.09
1896.....		5.23	12.70	8.25	10.97	.96	5.79	.60
1897.....	10.61	5.52	10.21	6.17	12.07	2.06	7.59	2.40
1898.....			7.42	4.25	10.76	.75	6.25	1.16
1899.....	7.71	4.36	5.74	5.24	7.31	2.70	4.99	.20
1900.....	7.05	2.70	7.41	5.28	7.30	2.71	4.25	.94
1901.....	10.06	5.22	5.37	1.93	9.06	.95	3.53	1.66
1902.....			4.66	2.87	7.50	2.51	5.74	.55
1903.....			9.09	3.25	8.12	1.89	3.61	1.58
1904.....			12.53	7.31	10.20	.19	6.54	1.35
1905.....	2.40	10.12	17.59	4.89	18.98	8.97	6.24	1.05
1906.....	11.60	4.31	10.79	5.60	11.15	1.14	4.45	.74
1907.....	17.85	9.10	11.69	7.53	11.23	1.22	6.07	.88
1908.....	6.29	2.63	4.50	2.19	7.41	2.60	3.94	1.25
1909.....	8.11	4.13	6.01	2.86	6.73	3.28	4.13	1.06
1910.....	7.62	2.84	3.42	2.78	5.50	4.51	3.02	2.17
1911.....	16.12	5.53	15.10	9.20	12.26	2.25	5.47	.28
1912.....	8.01	3.20	11.13	6.04	10.45	.44	5.52	.33
1913.....	8.10	2.37	11.44	6.18	10.67	.66	3.71	1.48
1914.....	17.81	8.71	17.55	8.81	16.87	6.86	7.44	2.25
1915.....	16.57	10.34	11.88	7.85	12.12	2.11	7.17	1.98
1916.....	16.38	5.61	15.28	8.38	12.23	2.22	5.24	.05
1917.....	4.69	3.02	3.40	2.30	5.31	4.70	3.88	1.31
1918.....	12.22	3.69	5.49	2.70	9.23	.78	2.92	1.87
1919.....	16.31	6.02	7.78	3.75	11.44	1.43	5.37	.18
Mean.....	¹⁰ 11.28	¹¹ 4.96	¹² 9.77	¹² 5.46	10.01	.....	5.19	.....

¹ Bold-faced figures for years below average; others average or above.² Bold-faced figures for amounts below normal; other amounts above normal.³ 56 years' records.⁴ 57 years' records.⁵ 22 years' records.⁶ 26 years' records.⁷ 41 years' records.⁸ 35 years' records.⁹ 36 years' records.¹⁰ 23 years' records.¹¹ 26 years' records.¹² 42 years' records.

The period from 1904 to 1907 is remembered by stockmen of southern New Mexico as exceptionally favorable for the cattle business, and there was prosperity during the period from 1911 to 1916. They are still talking about the severe drought of 1908 to 1910, inclusive, and live-stock production has not yet recovered from the



FIG. 4.—Map of New Mexico showing location of Jornada Range Reserve and rainfall stations.

drought of 1916-1918. Figures 2 and 3 show that the periods of prosperity in the business correspond to periods of approximately average or above in both seasonal and annual precipitation, and years of adversity to those below average. Figure 3 shows a similar dry period, from 1899 to 1903, inclusive, while figure 2 shows this dry period as from 1898 to 1901, inclusive. This difference is probably due to local variation in rainfall. Another similarly dry

period, 1889 to 1892, inclusive, with approximately average years back to 1886 is also shown in figure 2, and further records from the El Paso Station show exceptional precipitation in 1880 and 1884.

Further analysis of the precipitation data shows that for the years 1889 to 1892 the average annual precipitation was 34.1 per cent below the mean for the period 1886 to 1919; for 1899 to 1903 the departure below mean was 21.5 per cent; for 1908 to 1910, 34.6 per cent; and for 1916 to 1918, 10.9 per cent. During these same periods the average for the season July, August, and September was below the mean for these months for the whole period, 1886 to 1919, by 42.1 per cent in 1889 to 1892; 14.9 per cent in 1899 to 1903; 28.9 per cent in 1908 to 1910; and 22.8 per cent in 1916 to 1918.

Over 50 per cent of the mean annual precipitation falls during July, August, and September, and since the bulk of the range forage is produced primarily by perennial grasses which make their main growth during these months, it is not improbable that departure from mean precipitation for this growing season has a greater proportionate effect on the volume of forage produced and upon range maintenance than departure from mean annual precipitation. The effect of deficient precipitation during this period on the vegetation on the Jornada Range Reserve as later brought out seems to warrant this assumption.

For the present the main tentative deduction which seems warranted is that in cycles of 8 to 10 years there may occur 3 to 4 consecutive years during which precipitation is enough below the mean for the period to result in conditions considered by stockmen as drought. If future investigations can more definitely define the occurrence, duration, and intensity of these drought periods and the influence of seasonal precipitation, a big fundamental step will be made toward possible elimination of hazard connected with livestock production in this region.

PRECIPITATION ON THE JORNADA RANGE RESERVE.

Table 4 shows the precipitation by months, from 1914 to 1919, inclusive, with the exception of some data lacking in 1914 and 1915, for one station located at the headquarters ranch on the Jornada Range Reserve. Although rainfall in 1916 was slightly above the average for the year, there was a deficiency of 2.17 inches or 45.6 per cent departure from the average amount received during July, August, and September, the main growing season. The heavy rainfall occurring in October was too late for much benefit. During 1917 not only seasonal but annual precipitation as well was very deficient. In 1918 the amount of precipitation for the period of July, August, and September was not greatly below average for the region,

but the precipitation occurred in a few torrential rains during the latter part of July and early August, so that the moisture largely ran off and did not penetrate the soil to any great extent. Although vegetative growth started as a result of this precipitation, no more rains followed later in August or September, and a condition of drought actually existed until October over a large part of the reserve, as far as growing conditions were concerned.

TABLE 4.—*Monthly and annual precipitation for headquarters ranch station, Jornada Range Reserve, with departure from annual and seasonal (July, August, and September) average at State College, N. Mex.¹*

[Bold-face figures indicate amount below average. T=trace.]

Year.	January.	February.	March.	April.	May.	June.	July.	August.
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
1914.....	(²)	(²)	(²)	(²)	(²)	2.98	2.99	0.49
1915.....	0.49	1.12	0.95	0.09	(²)	T	1.40	1.91
1916.....	.25	.47	.79	.05	1.45	.00	.90	.96
1917.....	.47	T	T	.02	.39	.05	.57	1.52
1918.....	.78	.09	T	T	.05	.09	1.53	2.88
1919.....	.00	.00	1.50	.83	.28	.11	3.13	2.52

Year.	Septem-ber.	October.	Novem-ber.	Decem-ber.	Total annual precipi-tation.	Depart-ure from average at State College.	Total seasonal precipi-tation.	Depart-ure from seasonal average at State College.
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
1914.....	0.61	0.44	0.40	3.19	-----	-----	4.09	-0.66
1915.....	1.55	.00	.00	(²)	-----	-----	4.86	+ .11
1916.....	.72	2.63	.47	.19	8.88	+0.30	2.58	-2.17
1917.....	.25	.11	.16	.00	3.54	-5.05	2.34	-2.41
1918.....	.00	.96	1.71	.67	8.76	+ .22	4.41	-.34
1919.....	2.55	.64	.72	.50	12.78	+4.20	8.20	+3.45

¹ Data at Jornada Range Reserve station are compared with average at State College, since sufficient years' data are not available at Jornada Range Reserve for obtaining a reliable average over a period of years. The State College station is only 17 miles south of the reserve station, and about 300 feet lower in elevation, so that conditions are considered sufficiently similar to use the State College figures for comparison.

² Data lacking.

Average annual precipitation at State College, N. Mex. (59 years records)=8.58 inches; average seasonal precipitation at State College, N. Mex. (59 years, records)=4.75 inches.

The conditions as shown by the rainfall data at the one station on the reserve are fairly representative for the reserve as a whole. Some parts, however, received more rainfall during the growing season and others received less.

Uneven rainfall.—Within the territory represented by any of the stations for which precipitation records are given there may be great variation in the amount of precipitation on different portions of a single large range unit, or on different range units in any year or during the period of a drought. This variation results in a minor factor of uncertainty in anticipating what forage production may be expected on any given area, and necessitates a flexible general

plan of management in order to avoid local overstocking to the detriment of stock and range.

The possible extent of this local variation in precipitation is apparent from observations at the Jornada Range Reserve and vicinity from 1915 to 1919. In 1918 four additional rain-measuring stations were established on the reserve at distances of 7 to 13 miles apart. Table 5 shows precipitation at these stations in addition to the headquarters and State College stations.

TABLE 5.—*Annual and seasonal (July, August, and September) precipitation for New Mexico State Agricultural College and five rain stations on the Jornada Range Reserve, showing variation in amount within comparatively short distances.*

Year.	Agricultural College.		Headquarters.		South Well.		Red Lake.		West Well.		Ropes Spring.	
	An-nual.	Sea-sonal.	An-nual.	Sea-sonal.	An-nual.	Sea-sonal.	An-nual.	Sea-sonal.	An-nual.	Sea-sonal.	An-nual.	Sea-sonal.
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
1915.....	7.37	4.67	7.51	4.86	.....	.....	.....	.....	.....	.....	.....	.....
1916.....	7.78	2.47	8.88	2.58	.....	.....	.....	.....	.....	.....	.....	.....
1917.....	5.58	4.91	3.54	2.34	.....	.....	.....	.....	.....	.....	.....	.....
1918.....	7.23	2.71	8.76	4.41	5.47	2.39	7.06	3.88	5.87	3.16	8.89	3.70
1919.....	8.05	4.20	12.78	8.20	7.72	4.67	11.52	6.42	7.91	4.96	16.37	5.85

¹ Approximate.

Although no precipitation records are available, it is known from observations that the range unit adjoining the reserve on the south received more precipitation during 1917, a year of the recent drought, than fell on the reserve. In 1919, however, it probably received less precipitation than the reserve by an amount sufficient to make a difference in the current year's forage and in recuperation of range. The range unit north of the reserve received earlier rains and a greater total precipitation than the reserve in 1918 and 1919, a difference of sufficient importance to warrant a change from the pre-arranged plan of grazing the unit.

This possible variation is pointed out merely as one of many warnings against too heavy stocking of a range unit as a whole or a plan of management which is not reasonably flexible to meet such a situation by shifting stock from a local dry area to one of more abundant rainfall without disarranging the whole plan.

VARIATION IN FORAGE PRODUCTION.

Some measure of the volume of range forage which may be figured on seasonally, annually, and over a period of years, and the main factors responsible for variation, are fundamental in deciding the classes, numbers, and management of live stock. Drought and im-

proper grazing will be agreed to readily as the major factors responsible for variation in forage production. Other factors, such as "spotted" rainfall, soil, and character of vegetation necessitate adjustments in any general program of production. These adjustments are of little purpose, however, unless they are part of a comprehensive plan calculated to meet the conditions resulting from drought and from grazing use.

VARIATION DUE TO DROUGHT.

It is somewhat difficult to determine from data available the percentage of depreciation of the range as a direct result of drought, because records of changes in vegetation on areas protected against grazing have been collected only for the period 1915 to 1919, inclusive, and because part of the protected areas being studied were rendered unreliable by sand blowing on them in amounts sufficient to create unnatural conditions. However, the data available are important because they show, at least approximately, the changes which occurred in the main vegetation types during the drought of 1916 to 1918, and indicate the changes which will probably occur during a similar period in future years.

WINTER OR YEARLONG RANGE.

For the winter or yearlong type of range figure 5 indicates the annual change in density of good perennial forage grasses during the period 1915 to 1919, inclusive, with the annual precipitation for the same period. The actual amounts of good perennial forage grasses, inferior perennial grasses, long-lived weed¹⁰ vegetation, and short-lived plants per unit of area are given in Table 6. Only the good perennial forage grasses, mainly black grama and red three-awn, are used in establishing the curve indicating the change in condition of the vegetation, since these species represent the main grazing values of the range and are the ones most important to maintain. The vegetation curve is based upon quadrat chartings and observations on two representative areas of grama grass range, one protected against grazing from 1913 to 1919 and one protected from 1916 to 1919, inclusive. The protected areas were examined frequently each year, and quadrats were charted twice annually in 1915 to 1919, except 1918, when only one charting was made because of lack of vegetative growth early in the year.

¹⁰ "Weeds" as used in this publication mean all herbaceous vegetation other than grasses or grasslike plants.

TABLE 6.—*Amount and class of vegetation on inclosures protected from grazing and percentage of maximum stand, 1915 to 1919 inclusive (grama grass type).*

Year.	Good perennial forage grasses.		Inferior perennial forage grasses.		Long-lived perennial weeds.	Short-lived weeds and annual vegetation.
	Square centimeters ¹ per square meter.	Per cent-age of maxi-mum stand.	Square centimeters ¹ per square meter.	Per cent-age of maxi-mum stand.		
					Number plants ² per square meter.	Number plants ² per square meter.
1915.....	511	87.6	7	80	2.6	44.4
1916.....	583	100.0	8	90	3.0	33.0
1917.....	³ 537	92.1	7	80	17.5	61.5
1918.....	511	87.6	9	100	2.0	82.5
1919.....	347	59.5	8	90	0.0	31.5

¹ Actual measurement of area of grass tufts in square centimeters 1 inch above the ground on each square meter. (The metric system, with area expressed in square centimeters per square meter instead of with feet and inches, was used for convenience in the study because a unit of measure less than a square inch was necessary.)

² Actual count of number of individual plants per square meter.

³ Actual measurement showed 699 square centimeters but contained a considerable amount of dead forage mixed in with the living plants. This dead forage was estimated from best method of determination to be 23 per cent of total stand of vegetation.

Change in density of the grasses did not conform immediately to change in the rainfall. The main reason for this is the fact that the vegetation is dependent more directly upon available soil moisture than upon current precipitation, and the soil did not dry out to such a degree that it affected the growth so materially the first year of drought. In addition, however, the vegetation gradually decreased in vigor and resistance to unfavorable conditions, and further, there was difficulty in determining the percentage or total of dead grass until 1919. By 1917, the second year of the drought, the soil was becoming quite dry and the vigor of the grass had been considerably reduced. In 1918 the soil was so dry that a more nearly average rainfall occurring over a short period during the middle of the growing season did not materially improve growing conditions, and the weakened vegetation continued to die. In 1919 soil moisture was materially increased, but in the 1919 examinations considerable grass was found to be dead which had been classed as living in previous examinations. There was difficulty in determining the grass actually dead in 1918 on account of the absence of green growth and persistence of dry growth from previous years. In 1919, however, the dead growth had largely disappeared and the records are considered a reliable index of living vegetation.

The vegetation appeared to have reached its low point prior to the 1919 examination. Comparison of the conditions in 1919 with those of 1916, therefore, give the extent of range deterioration as a result of the drought on grama-grass areas not grazed. This depre-

ciation, amounting to 40.5 per cent, is believed to be approximately representative of the average depreciation of grama-grass range on

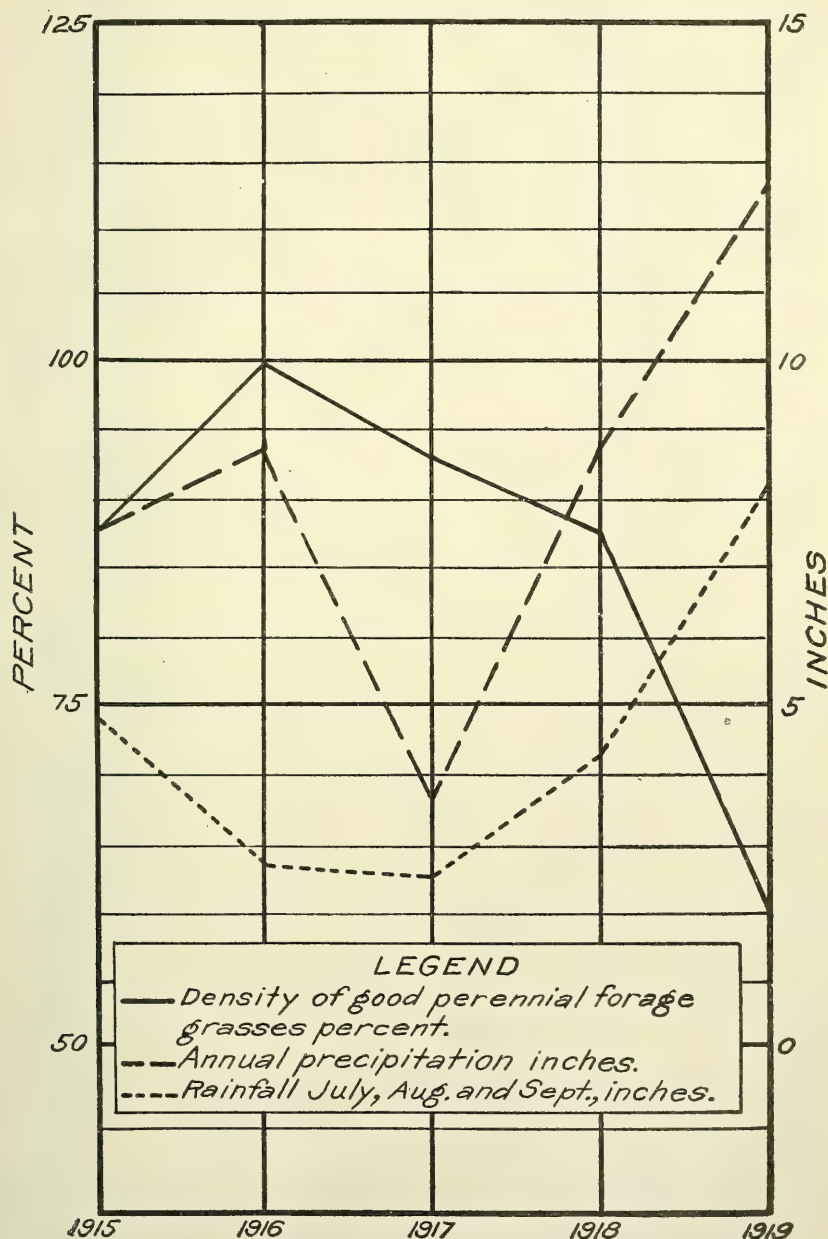


FIG. 5.—Density of good perennial forage grasses, on protected grama-grass range compared with annual and seasonal precipitation at the reserve.

the Jornada Range Reserve due to drought, although there is considerable variation. Plate II shows how this grass was killed out.

Areas of loose sandy soil dried out more quickly and were subject to greater injury than areas of the more compact finer textured soils. The difference was increased by the action of wind as well as difference in soil and moisture. Local areas of loose sandy soil were reduced to wind-blown wastes.

Because of the small amount of inferior grasses and long-lived perennial weeds on the two areas under study a conclusion as to the behavior of such vegetation is not warranted. This class of forage is not of great value except during wet springs, when it furnishes considerable early feed.

Vegetation of the character that usually lasts but a single year is not so materially affected by drought, because the plants depend upon the surface soil for their moisture, which might be supplied by showers at the proper season of the year, even during drought. The largest number of such plants occurred during 1917 and 1918, the driest years of the drought. This might easily occur, since the high winds increased dissemination and planting of the seeds, the rain that fell was sufficient to moisten the surface soil to promote growth, and competition by the main grasses had diminished. The volume of forage furnished by this kind of vegetation on range used in winter is negligible, however, since the plants dry up and blow away soon after the growing season.

Aside from the reduction in density of the forage stand due to drought, there was also a reduction in the height and foliage growth which further reduced the volume of forage. In 1917 the average height growth of ungrazed grama-grass was 13 inches, in 1918 it was only 8.6 inches, while in 1919, a year of more moisture, the average height growth reached 16 inches. It was difficult to measure in actual terms of quantity the difference in volume of forage produced due to variation in height and foliage growth on the ungrazed plots, because the previous year's foliage was not removed and the dryness of the plants made it difficult to determine the amount that was actually dead. Careful estimates, however, placed this reduction in 1917 and 1918 in volume of forage produced per unit area of vegetative stand at not less than 20 per cent of the amount produced under average condition. More nearly average height growth and foliage production was reached in 1919 by the plants that survived the drought.

From the grama-grass range under protection against grazing the data and estimates indicate a reduction in the stand of the most important forage plants of 8 per cent in 1917, 12.4 per cent in 1918, and 40.5 per cent in 1919, as compared with the stand in 1916. One of the plots observed had been under protection since 1913, the other since 1915, so that the stand in 1916 was probably near the maximum for the two sites which were chosen as representative of this type of

range. The figures for 1917, and especially for 1918, however, may be too low, because of the difficulty of determining under the dry con-



FIG. 6.—Volume of forage on tobosa grass, summer range, compared with precipitation.

ditions prevailing just what plants were dead; but the reduction to 59.5 per cent of the original stand in 1919 is believed to represent the

actual amount of living forage. It is undoubtedly true, however, that depreciation is much greater in the third year of drought than in either the first or second year, on account of the increased desiccation of the soil and lowered vitality of the vegetation. Adding to this depreciation in stand the estimated 20 per cent decrease in volume due to decrease in height and number of leaves produced per living plant in 1917 and 1918, the volume of forage by years was about 100 per cent in 1916, 73.6 per cent in 1917, 70.0 per cent in 1918 and 59.5 per cent in 1919.

Summer range.—Table 7 and figure 6 show what occurred in the density of vegetation on the main summer range type during the drought on a representative area protected from grazing during the summer and fall of each year. Since at other times of the year forage on this type is of low palatability and therefore but lightly grazed, the area used is representative of yearlong protection. The quadrat on this area was charted and observations made annually, with the exception of 1917, when the vegetation was too dry to chart and only observations were made.

TABLE 7.—Amount of vegetation, percentage of maximum stand, and percentage of maximum volume of forage on tobosa-grass range, 1915 to 1919.

Year.	Amount of grasses (square centimeter) per square meter.	Percentage of maximum year.	Volume of forage produced, in percentage of maximum year.
1915.....	928	100.0	100.0
1916.....	928	100.0	100.0
1917.....	930	100.0	45.0
1918.....	935	100.0	55.0
1919.....	656	70.1	70.1

The density of the forage on the tobosa-grass range remained practically stationary during 1916, 1917, and 1918, so far as it was possible to determine. During 1919, as the result of the accumulated effect of the drought, it decreased 30 per cent. It is probable that part of the 30 per cent died prior to 1919, although final removal of dead grass did not occur until 1919.

Height growth and foliage production were reduced about 55 per cent in 1917 and 45 per cent in 1918, but were approximately average in 1919. Considering the volume of forage in 1916 as 100 per cent, the estimated volume in 1917 was 45 per cent; in 1918, 55 per cent; and in 1919, 70.1 per cent.

The results from the study of the tobosa or summer-range type show a greater reduction in volume of forage produced in dry years as compared with protected grama-grass range, but density of the

stand in the tobosa type is not decreased nearly so much in time of continued drought as in the grama-grass type. Furthermore, improvement of the tobosa type is likely to occur immediately with the first wet year, while in the case of the grama-grass type several years will probably be required for this recovery. The great reduction in volume of forage produced in the tobosa-grass type in a dry year appears to be due to a greater moisture requirement for growth than in the case of the grama type species. The lesser reduction in density of the stand in the tobosa type in time of prolonged drought is evidently due to the ability of these species to lie dormant longer without moisture before dying than is grama-grass, and to a finer-textured and more compact soil which has a greater air-dry moisture content than the looser sandy soils of the grama-grass type. Although tobosa-grass probably has a greater drought resistance, the volume of forage produced is affected more directly by the amount of moisture that falls.

Studies of tobosa-grass areas fully grazed during summer showed approximately the same depreciation on these as on areas not grazed, which indicates that this type of range can be grazed fully during the growing season without injury in time of drought as well as in good years. The main difficulty with this type in time of drought is the big decrease in foliage production rather than killing out of the range, as shown in figure 6.

VARIATION DUE TO GRAZING.

The preceding discussion is intended to bring out the amount and variation in forage production on certain areas of the Jornada Range Reserve protected against grazing. This measure of natural production indicates the maximum forage which will probably be available for use over a period of years under natural conditions, and is a standard with which to compare production on similar ranges under different grazing use so as to adjust grazing in a way which will maintain the range and support the maximum stock over a period of years, including drought. A comparison of this nature has been made for the period 1915 to 1919, inclusive. The conditions studied include ranges where grazing has been excessive yearlong for a period of years, where grazing has not been too heavy for the year as a whole but only during the main growing season, and where grazing has been heavy for the year as a whole but much lighter than average during the main growing season. A description of the areas and how they were grazed, with the results and conclusions, is here presented.

OUTSIDE RANGE.

Adjoining the Jornada Range Reserve on the west is an area of about 98,530 acres, of which about 66,485 acres are the grama-grass type. The remainder is primarily of mixed-grass type of less grazing value than the grama grass. This area is controlled by private individuals and was used to study unregulated grazing as compared with regulated grazing on the reserve. Potentially, this range is as good as the protected plots on the reserve or better, as is indicated by the density and kind of vegetation at points so remote from water that stock have rarely ever more than lightly grazed it.

In 1915 this outside range supported on the average only 45.4 per cent as much good forage grasses as similar range in about maximum condition under complete protection against grazing. Of inferior grass forage, however, the outside range had 14 times as much as the protected area. The amount of other vegetation did not differ greatly. As a whole, the outside range was considered in condition about 50 per cent of the maximum under average growing conditions, when the drought began in 1916. This state of depletion was attributed to yearlong overstocking, over a period of years previous to 1916.¹¹

Heavy yearlong grazing was continued on this area during 1916-17 and the early part of 1918. In the spring of 1918 and during 1919, however, it was almost completely protected against grazing during the main growing season, July 1 to October 1, and the forage was fully utilized during the remainder of each year, but the area was not overstocked.

PASTURE 2 OF THE JORNADA RANGE RESERVE.

Pasture 2 of the reserve contains about 34,545 acres adjoining the outside range described on the east. It is primarily grama-grass range. This pasture had been lightly grazed during the main growing season and slightly undergrazed for the year as a whole, for three years prior to July 1, 1916, as shown by Table 8, and under this management had improved about 50 per cent as compared with similar range grazed year long. In 1915 pasture 2 was considered slightly better in amount of forage per unit of area than the protected areas, and almost as good as the maximum later reached by the protected areas.

¹¹ Fully discussed in Department of Agriculture Bulletin 588.

TABLE 8.—Rate of stocking during year, percentage of reduction of stocking during growing season, percentage of utilization of forage, and reduction in forage stand in pasture 2, 1913 to 1919.

Year.	Actual acres per cow year long.	Percentage reduction in average yearly stocking from 1913 rate.	Percentage decrease or increase in grazing during growing season compared with yearly average.	Percentage utilization of forage at close of grazing season.
1913.....	26.6	-----	-35.3	100
1914.....	47.0	43.5	-62.1	57
1915.....	33.1	19.8	-30.8	80
1916.....	43.9	39.3	02.6	90
1917 ¹	44.3	40.1	44.6	125
1918.....	90.2	71.5	36.1	90

¹ 82,900 pounds of cottonseed cake were fed to stock in this pasture in the spring of 1918. While this feeding served largely to keep cattle from getting too poor it allowed utilization approximately 25 per cent above estimated proper rate of stocking.

Table 8 shows that this pasture was stocked at approximately the annual yearlong rate during the growing season of 1916, but that during 1917 and 1918 stocking was considerably heavier during the growing period at this season than for the year as a whole.

PASTURE 5 OF THE JORNADA RANGE RESERVE.

Pasture 5 of the reserve is an area of 2,815 acres primarily of good grama-grass range. In the spring of 1915 this area was about 44 per cent below what it should have been, and deterioration was attributed largely to overstocking during the main growing season for several years previous. In 1916 the average number of stock in this pasture was reduced 35.5 per cent, with a slightly greater reduction during the growing season; in 1917 the average number of stock was reduced 33.8 per cent from the rate during 1915, and 54 per cent during the growing season; in 1918 the average for the year was again heavier than the 1915 stocking, but during the growing season grazing was less than 50 per cent of the average for the year.

RESULTS OF THE VARIOUS DEGREES AND PERIODS OF GRAZING.

The effects of the condition of drought prevailing and different time and degrees of grazing practiced on the various areas are shown in Table 9 and compared graphically in figure 7.

Under the conditions of drought and grazing prevailing during 1916 the outside range about held its own as compared with 1915, but it deteriorated 21.5 per cent in 1917 and 39.9 per cent further in 1918. In 1919 there was a slight but real gain in conditions, so that the total deterioration during the drought period was about 60 per cent as compared with the condition of this range in 1916. The

slight improvement in 1919 is attributed to the protection from grazing during the growing season in 1918 and 1919. As compared with

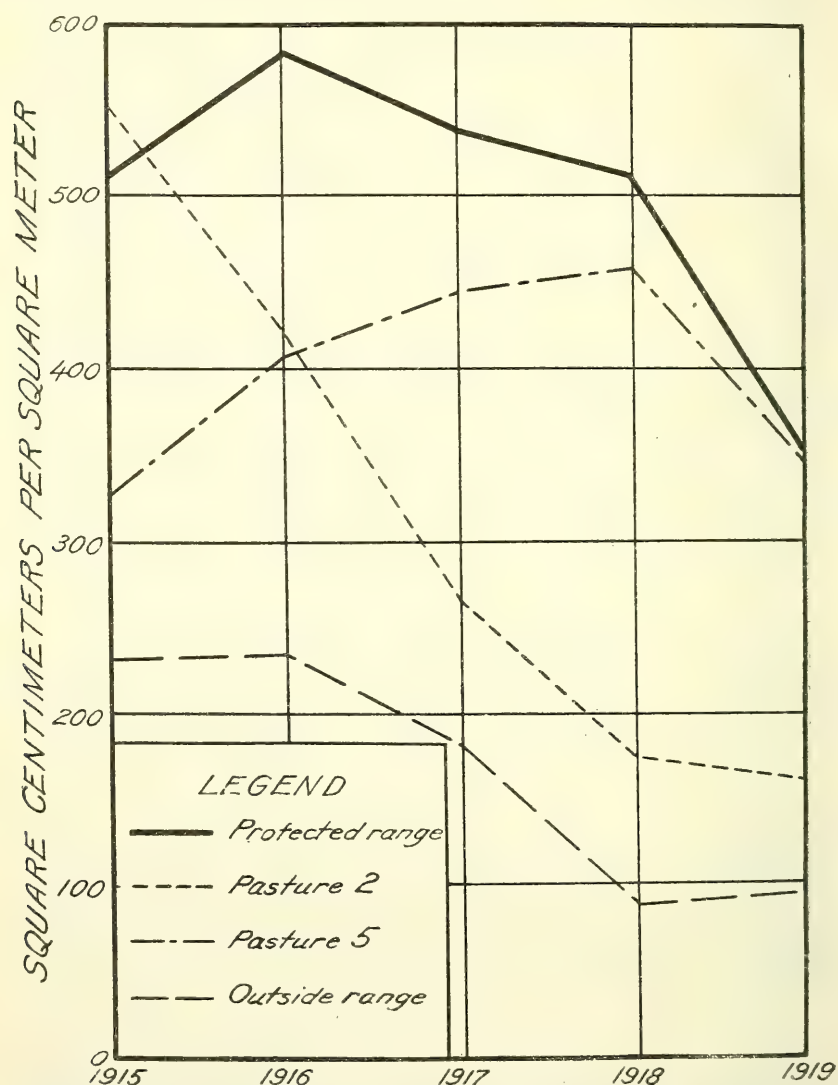


FIG. 7.—Comparison of density of good grass forage on outside range, pasture 2, pasture 5, and protected range, 1915–1919.

NOTE.—Pasture 2 was in good condition in 1915 as a result of protection during main growing seasons of 1913–1915. Grazing was not reduced during main growing seasons 1916–1919. Pasture 5 was run down in 1915 as a result of previous improper grazing. It received light grazing during main growing seasons 1916–1919 with full use rest of the year. Outside range was badly run down in 1915 as a result of previous improper grazing. Heavy yearlong grazing continued till 1918. Light grazing prevailed during growing seasons 1918–19.

the amount of forage on the protected areas in 1915 the outside range was only 45.4 per cent as good that year and only 17.6 per cent as

good in 1918. The slight improvement of this range during 1919 and continued deterioration of the protected areas made the former 27.1 per cent as good as the latter that year. This difference in action on the two areas in 1919 is attributed to the fact that the protected areas with over 80 per cent of a maximum stand had more vegetation than the available moisture would support, and the result was heavy depreciation. On the other hand, the outside range, with less than 30 per cent of a maximum stand and approximately equal average moisture conditions, made improvement when protected during the main growing season for two years. This conclusion is supported by the records given later for pasture 5.

TABLE 9.—*Variation in density of grama grass on protected areas, outside range, pasture 2, and pasture 5, and comparison of grazed ranges with protected areas, 1915 to 1919, inclusive.*

Year.	Protected areas—Range protected from grazing yearlong.		Outside range.—Range heavily grazed yearlong until 1918; very light grazing during growing season in 1918 and 1919.		Pasture 2—Range grazed yearlong without overgrazing, but no reduction in grazing during growing season after 1915.		Pasture 5—Reduced grazing during growing season since 1915 but fully utilized during the rest of the year.		Percentage of forage on grazed range as compared to protected range each year.		
	Amount of grass, square centimeters per square meter.	Percentage of maximum year.	Amount of grass, square centimeters per square meter.	Percentage of maximum year.	Amount of grass, square centimeters per square meter.	Percentage of maximum year.	Amount of grass, square centimeters per square meter.	Percentage of maximum year.	Outside range.	Pasture 2.	Pasture 5.
1915....	511	87.6	232	99.6	553	100.0.	326	71.2	45.4	108.2	63.8
1916....	583	100.0	233	100.0	421	76.1	405	88.4	39.9	72.2	69.4
1917....	537	92.1	183	78.5	269	48.6	444	96.9	34.0	50.0	82.6
1918....	511	87.6	90	38.6	177	32.0	458	100.0	17.6	34.6	89.6
1919....	347	59.5	94	40.3	165	29.8	343	74.8	27.0	47.5	98.8

Pasture 2 showed steady depreciation from its maximum stand in 1915 to 32 per cent of this stand in 1918 and 29.8 per cent in 1919. As compared with the amount of forage on the protected areas the pasture was 27.8 per cent lower in 1916, 50 per cent in 1917, and 65.4 per cent in 1918. Granting that the figures for the protected-area curve are too high for 1917 and 1918, because of difficulty in determining the amount of dead grass, as explained on page 20, and that the 1919 curve point more nearly represents the depreciation due to the drought factor, there is still a difference of 52.4 per cent in favor of the protected areas as compared with pasture 2 range. The greater loss in pasture 2 is attributed primarily to the heavy grazing during the main growing season in 1916-17 and in 1918, and approximately full stocking the rest of the year, as shown in Table 8. The soil in pasture 2 is not as compact as that in the protected areas or in pasture 5, and consequently dried out more quickly. In addition, the area was slightly overgrazed in 1917, but this slight over-

grazing and difference in soil could hardly account for more than a small amount of the difference in depletion had the area not been grazed, or had grazing been greatly reduced during July, August, and September. The low point of the pasture 2 curve in 1918 and 1919 as compared with the curve for similar range protected from grazing would indicate that the lack of available moisture for the existing stand of vegetation was not a prime factor in depreciation had the area not been heavily grazed during the growing season. This view seems warranted from the further facts brought out in the study of changes in the outside range when given protection during the growing seasons of 1918 and 1919, and because pasture 2 itself showed marked improvement under light grazing during the growing seasons of 1913 to 1915, inclusive.

Table 9 and figure 7 show that the stand of good grass forage in pasture 5 continued to increase up to 1918, when it reached its maximum for the period, but dropped 25.2 per cent in 1919 and showed practically the same amount of forage per unit of area as the protected areas at that time. Although these results differ from those on other areas under study, they appear warranted when all facts are considered. Soil conditions are slightly more favorable in this pasture than for the average grama-grass type, and the area received a few more light showers and slightly greater total rainfall than the average for the type in 1916 and 1918. In addition, the poor condition of the pasture in 1915 made available much opportunity for improvement. These advantages, combined with reduction in grazing during the main growing season, especially the latter, are thought to account for the steady increase up to 1918. Plate II compares the results of heavy yearlong grazing with reduction of grazing during the growing season.

The drop in condition in 1919 is partly explained by the average overgrazing during 1918, but was probably due more to the fact that the density of the vegetation had reached a point where it was greater than the available moisture would support and, consequently many of the young plants died late in 1918 and early in 1919 before the rainy season began. The study shows that the stand of good forage grass in pasture 5 at all times during the period was less than on the range totally protected against grazing. It is apparent, therefore, that except for the effect of grazing the pasture would support the increase in vegetation shown. The drop from 1918 to 1919 is consistent with the depletion on the area under protection and indicated that both of these areas had deteriorated to about the maximum stand that available moisture of 1918 would support. The lack of improvement in 1919, which was a wet year, on these two areas indicated further that abundant moisture alone is not sufficient for improvement after drought; at least one good year following drought

is necessary for the grama grass to recuperate in strength sufficiently to set about any material increase in density on ranges that have been maintained as high as available moisture would support during drought.

OVERSTOCKING.

That depreciation of the range will result from overstocking under any system of use is obvious, and too much emphasis can not be given to necessity for care, first in adjusting grazing use so as to give the main forage plants as much chance to grow as possible, consistent with good management of the stock, and then to avoid putting more stock on any area than it will carry under the plan of use decided upon.

The occurrence on the outside range (Table 9 and fig. 7) illustrates what may happen to a grama-grass range where care is not exercised. The only system of use possible on this area up to 1918 was yearlong grazing. No real effort was made properly to limit the number of stock to what the range would carry, and as a consequence, the range was only 45 per cent of what it should have been in 1915. As a result of the continued overgrazing it had depreciated to 17 per cent of what it should have been in 1918, near the end of the drought. As a direct consequence losses of live stock were excessive and the calf crop was greatly reduced. Furthermore, many of the more valuable forage plants were replaced by less valuable or worthless ones.

The condition of pasture 5 of the Jornada Range Reserve in 1915 showed also the results of overgrazing. Grazing for the year ended June 30, 1916, was considered 25 per cent too heavy, and indications were that the area had been overstocked previous to June, 1915. As a consequence the range in this pasture in 1915 was 41 per cent poorer in density of stand than that of pasture 2 adjoining, where both seasonal and annual grazing were more nearly correct.

Depreciation in pasture 2 of the reserve during the period 1917 to 1919, as shown in figure 7, is greater than is warranted even in time of drought. This depreciation most probably could have been reduced by lighter stocking during the main growing season without materially lowering the average for the year. Since this was difficult to arrange because of shortage of forage elsewhere, the average for the year should have been lower, or at least provision should have been made for the necessary reduction in stocking during another drought.

Indications of overgrazing.—Without careful records of grazing and range conditions covering a long period of years it is difficult to decide exactly the maximum stocking which will probably be possible without range depreciation. The result is likely to be slight

understocking with some loss of forage, or overstocking and consequent injury to the range. Although it would be far better and cause less loss of forage in the long run to understock slightly each year, the tendency in the past has been toward overstocking. Until the proper rate of stocking has been determined, however, careful observation of range and stock should make possible the detection of deterioration in time to provide for recuperation in a few seasons.

Overgrazing on grama-grass range in the Southwest may be recognized to some extent in its first year by observations of the degree of cropping of the grass. Ordinarily grama grass should not be cropped closer in any year than will leave the lower joints of a few grass stalks on each tuft. This will provide a means of revegetation under favorable conditions the next year.

Black grama grass reproduces mainly by *stolons*. A number of the mature flower-stalks of each plant bend to the ground, sending forth a crown of leaves at each node or "joint" which takes root when it strikes the soil. Eventually as the little plants become established the connecting part dies and an independent plant is thus formed. If the grass is grazed so closely that no nodes are left there is no opportunity to revegetate by this method.

In loose soil overstocking results in the trampling and loosening of the surface soil so that the roots of the grasses are exposed and wind erosion begins. If the stock grazing an area fall off in condition faster than other causes warrant, overstocking is no doubt occurring.

Following the first year of overgrazing unpalatable annual grasses and weeds and short-lived perennial plants usually increase along with a reduction in number of leaves and height of the grass and in the number of flowering stalks and *stolons*. These secondary species increase with continued overgrazing and deterioration of the range until they are the only vegetation present. This is the case within a radius of one-half mile around some stock-watering places in the Southwest. The main plants indicating the first stages of deterioration in the grama-grass range of southern New Mexico are such *annuals* and *short-lived perennial* plants as tall eriogonum, sixweeks grasses, spectacle-pod, whitestem, and yellow caltrops.

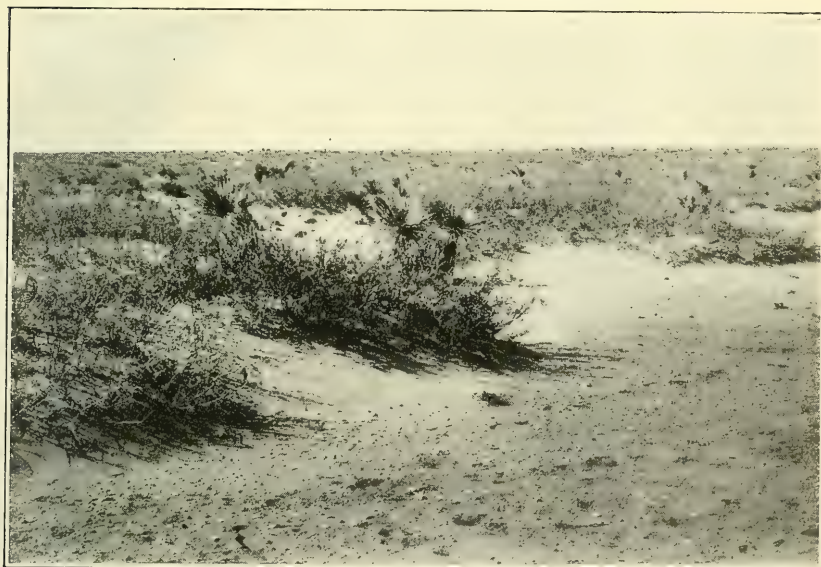
The best indicators of later stages of deterioration are *dropseed grasses*, *leatherweed*, *silvery nightshade*, and *yellowbush*, followed by *snakeweed*, and finally the mesquite-sandhill type if overgrazing and wind erosion is allowed to continue too long.

Where overgrazing has reached the stage where mesquite sandhills are being formed it will be difficult to restore the range. Effort should be made to detect the breaking down of the range much earlier, or as soon as the annuals and short-lived perennials begin to increase and the good grasses to decrease. Figures 1 and 2,



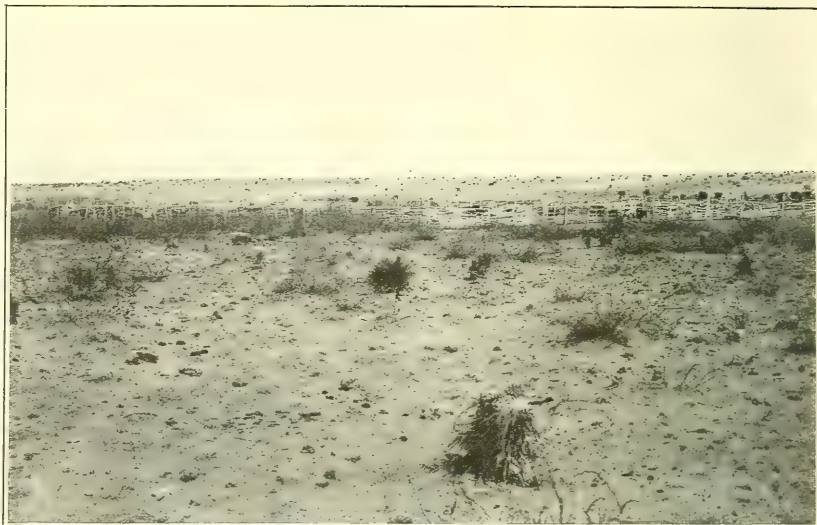
F-46456-A

FIG. 1.—SNAKEWEED IS ONE OF THE MOST COMMON PLANTS FIRST TO “TAKE THE RANGE” WHEN OVERGRAZING OCCURS TO THE EXTENT THAT THE BETTER FORAGE GRASSES ARE KILLED OUT.



F-38571-A

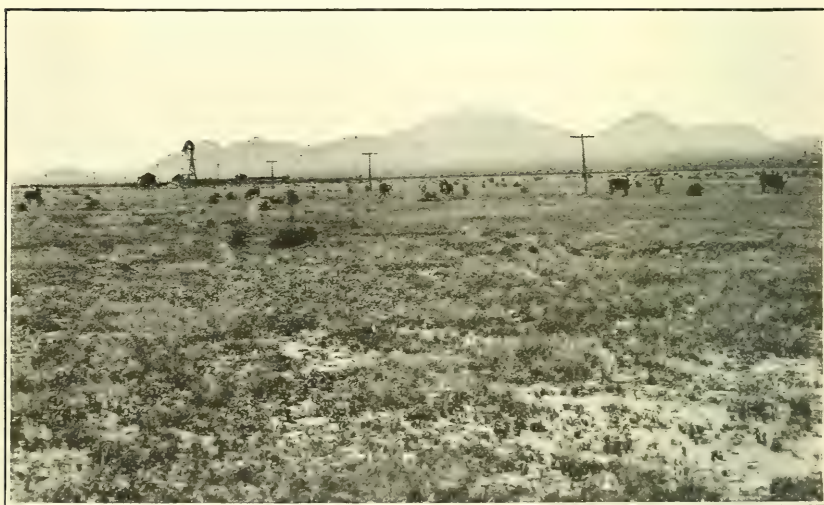
FIG. 2.—THE ULTIMATE RESULT OF INJUDICIOUS GRAZING MAY BE A TRANSFORMATION OF A GRAMA-GRASS RANGE TO THE MESQUITE-SAND-HILL TYPE. BREAKING DOWN OF THE RANGE SHOULD BE DETECTED LONG BEFORE THIS STAGE AND STEPS TAKEN TO REPAIR IT.



F-35175-A

FIG. 1.—A BADLY CONGESTED WATERING PLACE ON THE OPEN RANGE WHERE THE DISTANCE BETWEEN WATERING PLACES IS 7 TO 12 MILES.

The result of great distances between waters is overgrazing and killing out of the best forage near water, with under-utilization beyond a distance of 4 miles on level range.



F-40713-A

FIG. 2.—WHEN WATERING PLACES ARE NOT MORE THAN 5 MILES APART ON LEVEL RANGE AND THERE IS NO OVERSTOCKING, STOCK SECURE EVEN UTILIZATION OF THE RANGE AND THE VEGETATION EXTENDS ALMOST UP TO THE WATER.

Contrast with fig. 1 where there is very little good forage within a mile of water.

Plate III, illustrate the successive stages of the effects of overgrazing.

FORAGE PRODUCTION CONCLUSIONS.

Conclusions from the forage-production data obtained thus far may have to be changed when data from observations through another drought period are available. These tentative conclusions point the way, however, toward certain essentials in determining the grazing capacity of the range and are a basis for adjusting grazing management and use preparatory to the next drought. The main points indicated by the study so far are:

(1) Grama-grass range similar to that on the Jornada Range Reserve begins to die out the second year of drought, and when a drought lasts three years the stand of forage on ungrazed range may be reduced as much as 40 per cent. The volume of forage produced per unit of area is further reduced by decreased height growth and foliage production during dry years. The vigor of the grass is affected to such an extent that at least one good year following drought is necessary before the range will begin to improve in density. In the case of tobosa-grass range there is less dying out of the grass, amounting to only 30 per cent in the third year of drought, but the volume of forage produced per unit of area is affected more directly by the amount of moisture received. The actual reduction in the amount of forage produced at the worst of the drought, taking into consideration both reduction in density and reduction in foliage production is about 50 per cent of the amount produced in good years on both grama-grass and tobosa-grass range.

(2) The depreciation of grama-grass range is greater as overgrazing increases and especially under too heavy grazing during the main growing months—July, August, and September. If grazing on it is reduced approximately one-half the year-long rate during July, August, and September, and if it is not too heavy the rest of the year, grazed range may be maintained in about the same condition as ungrazed and run-down range may improve to approximately the same condition. Apparently tobosa-grass range may be grazed heavily during the growing season, whether or not there is drought, without affecting it materially.

(3) Overgrazing a range results in a decrease in the best forage species on the range and their replacement by plant species of less forage value.

(4) In time of drought so great a reduction as 50 per cent of the volume of forage produced in more nearly average years may be expected and should be prepared for. Grazing should be reduced on grama-grass range during the main growing season, July, August,

and September, but grazing at that time does not seem to affect tobosa-grass range, so that the latter should be used for summer range and the former at other times. Should grama-grass range be overgrazed this fact may be detected by the various plant species that come in on the range and steps should be taken to reduce grazing and protect the range during the growing season.

GRAZING CAPACITY.

The effect of drought and time of grazing upon the grazing capacity of the range is of prime importance in working out a plan of management to secure maximum maintained cattle production on southwestern ranges. The summary given in the last few pages shows that there is a great reduction in amount of forage produced per unit of area due to drought and considerable variation due to difference in the time and extent to which the grama-grass range is grazed. The data show also that the reduction increases with each year of drought. Should the first few years following drought be favorable an increase in forage production toward the maximum will undoubtedly occur. To determine approximately what these changes mean in number of stock or percentage of stock, from year to year throughout a cycle including a drought and the good years following, is a problem that must be solved if similar conditions are to be prepared for in advance and the "downs" of cattle production on ranges of the Southwest be reduced or eliminated.

By grazing capacity is meant amount of grazing that may be secured per unit area. Usually this amount is expressed, however, in acreage per head of stock on any given range for the period the range is used. On most of the southern New Mexico ranges the stock are grazed yearlong. Grazing capacity is therefore expressed in terms of acres per head for the yearlong period, or, in other words, acreage required to furnish a year's grazing for one animal, although grazing may be lighter than average during part of the year.

True grazing capacity obviously is the acreage of a given range required to support one animal of a given class over a period of years without injury to the range. This ideal is difficult to attain on any range and is especially so on ranges of southern New Mexico, which are subject to the changes and variable factors briefly discussed in preceding pages. It is hoped, however, by careful records and adjustments over a period of years to approach the ideal closely enough to avoid unwarranted waste of forage through nonuse and certainly to avoid the serious overstocking common in the past. Improvement in grade of stock and comparatively higher prices for better stock in thrifty condition will aid in approaching the ideal by making it profitable to insure proper care of the stock through

sufficient range forage and supplemental feeding. Rapid advancement in this respect has already taken place in the past few years.

Along with the records of change in vegetation under protection against grazing and undergrazing over the period 1915 to 1919, inclusive, daily records have been kept of the animal days feed furnished by each of the pastures on the Jornada Range Reserve, and approximate figures by seasons for adjoining and nearby unfenced ranges have been obtained.

YEARLONG OR WINTER RANGE.

The main portion of the yearlong or winter range, consisting of the pure grama grass, part of the mixed grass, the snakeweed, and the mesquite-sandhill types on the Jornada Range Reserve occurs in pastures 2, 5, and 10. Carrying-capacity data for these pastures and for similar outside range grazed yearling (Tables 10, 11, 12, and 13) show the reduction in carrying capacity during drought and the effect of the time and degree of grazing.

In the tables condition of the range, in each case, with the exception of pasture 10, is compared with the protected areas for each year when such data were available, to eliminate approximately the factor of moisture and get at the influence of grazing alone in causing range depreciation.

TABLE 10.—*Grazing capacity of pasture 2, 1913 to 1919.*

[Area of pasture, 34,545 acres.]

Period, July 1 to June 30.	Average acres per head per year (365 days).	Estimated per cent of available forage utilized.	Estimated grazing capacity in acres, per head.	Condition of range in per cent of condition on protected area.
1913-14.....	26.6	100	26.6	-----
1914-15.....	47.0	57	26.6	-----
1915-16.....	33.1	80	26.5	108.0
1916-17.....	43.9	90	39.5	72.2
1917-18.....	42.6	125	53.2	50.0
1918-19.....	93.6	90	81.2	34.6
1919-20.....				47.5

¹ 80,900 pounds of cottonseed-cake fed in this pasture during the spring of 1918, which increased utilization 25 per cent.

TABLE 11.—*Grazing capacity of pasture 5, 1915 to 1919.*

[Area of pasture, 2,815 acres.]

Period, July 1 to June 30.	Average acres per head per year (365 days).	Estimated per cent of available forage utilized.	Estimated grazing capacity in acres, per head.	Condition of range in per cent of condition on protected area.
1915-16.....	23.1	125	28.1	63.8
1916-17.....	36.0	100	36.0	69.5
1917-18.....	35.2	100	35.2	82.7
1918-19.....	22.3	125	27.9	89.6
1919-20.....				98.8

TABLE 12.—*Grazing capacity of pasture 10, 1915 to 1919.*

[Area of pasture, 4,805 acres.]

Period, July 1 to June 30.	Average acres per head per year (365 days).	Estimated per cent of available forage utilized.	Estimated grazing capacity in acres, per head.	Condition of range in per cent of condition on protected area.
1915-16.....	32.5	85	27.6	.....
1916-17.....	43.2	90	39.0	.....
1917-18.....	20.1	¹ 183	36.8	.....
1918-19.....	33.5	100	² 33.5	.....

¹ 64,500 pounds of cottonseed cake were fed in this pasture during winter and spring of 1918, which increased utilization 83 per cent.

² Mostly short-age yearlings in the pasture.

TABLE 13.—*Estimated grazing capacity of outside range, 1914 to 1919.*

Period, July 1 to June 30.	Average acres per head per year (365 days).	Estimated per cent of available forage utilized.	Estimated grazing capacity in acres, per head.	Condition of range in per cent of condition on protected area.
1914-15.....	26.3	125	32.9	.....
1915-16.....	26.3	125	32.9	45.4
1916-17.....	32.8	125	41.0	40.0
1917-18.....	81.1	125	101.4	34.2
1918-19.....	98.5	100	98.5	17.6
1919-20.....	.....	.....	.....	27.1

A comparison of these tables shows that estimated carrying capacity of the four areas was approximately the same for the annual period ending June 30, 1916. Pastures 2 and 10, with an average of 27 acres per head per year, were probably at their maximum average carrying capacity in 1915-16, having had the opportunity to reach this condition through very light grazing during the growing period for several seasons previous. Pasture 5 and the outside range were slightly below their maximum on account of overstocking yearlong with no opportunity for recuperation during the growing season for several years previous.

Table 10 shows that the average grazing for each year in pasture 2 exceeded the estimated grazing capacity for the respective year only in 1918, and that the excess in 1918 was due mainly to the feeding of 80,900 pounds of cottonseed cake to stock in the pasture. It is probable that the average grazing for the year was slightly in excess of the amount of forage. This slight excess, however, does not account for the depreciation of pasture 2 from 108 per cent of the protected areas in 1915-16 to 34.6 per cent of the same protected areas in 1918-19. As pointed out in the last chapter this seemingly unwarranted depreciation was attributed primarily to the failure to reduce grazing during the growing season, July to October.

Table 11 shows that, although pasture 5 was grazed more heavily on an average each year than pasture 2, the range improved in production of the main forage grasses and increased slightly in carrying capacity each year after 1916-17. The pasture was considered overstocked only in 1915-16 and 1918-19, and stocked about right the other years. Although heavily stocked the pasture held up well, probably as a result of reduction in grazing during the main growing season. Comparison of pastures 2 and 5 indicates that it was not overgrazing but heavy grazing during the growing season that was responsible for deterioration of pasture 2, and that the pasture would have sustained as an average for each year the number of stock actually grazed if grazing during the growing season had been more judicious.

Pasture 10 (Table 12) agrees rather closely with pasture 5 in estimated grazing capacity for the period. The actual difference was perhaps a little greater than shown in the tables in favor of pasture 5, as the drought was more severe in pasture 10 and in 1918 mainly short-age yearlings were grazed in the pasture, this class of animals requiring less range per head than cows. As in pasture 5, the prime factor in keeping this pasture up in carrying capacity was reduction in grazing during the main growing season.

Table 13 shows that the average grazing on the outside range exceeded the estimated grazing capacity each year with the exception of 1918-19, and that, except in 1918-19, the grazing capacity as well as the condition of the outside range in comparison with the protected areas continued to decline up to 1919-20. The overgrazing during the whole year no doubt contributed a great deal to the decline in productivity of the range, but the overgrazing during the growing season, as brought out in the last chapter, was mainly responsible for the heavy reduction in the condition of the forage and grazing capacity. The slight increase in the grazing capacity in 1918-19 and the improvement in condition of the range in 1919-20 is largely due to the reduction in number of stock to more nearly what it should be, and light grazing during the main growing seasons of 1918 and 1919.

The information obtained on yearlong winter range to date indicates that, while decreased grazing capacity will result during drought, the reduction may not be greater than the amount due to drought alone if the range is correctly managed. The main consideration is to handle the range so that grazing will be light over as much of this class of range as possible during the main growing season—July to October. Without this provision the range will deteriorate faster during time of drought, varying with the time and intensity of grazing.

The estimated grazing-capacity figures in Tables 10, 11, and 12 are computed from careful observations and estimates in each pasture by years on the basis of rather full use of available forage each year without knowledge or special consideration of what conditions would be the succeeding year. This method was followed because there was little chance for change except to increase supplemental feeding while the drought was on, and it was desired to have a close estimate of total grazing capacity by individual years as a basis for the progressive adjustments for a similar period in the future. While the stock on the reserve was carried over the drought with a maximum annual loss of 3.5 per cent as compared with a maximum annual loss of about 35 per cent for the surrounding country, without more feeding than will probably be profitable during another similar period, and without injury to the range other than caused by drought alone, except in pasture 2, the experience during 1916 to 1919 warrants a greater margin of safety even than would be provided by the estimated grazing-capacity figures given. This conclusion seems warranted considering the great worry and strenuous effort to prevent losses, the rather large reduction in calf crop, and the lack of satisfactory growth of young animals, especially during 1917 and 1918. Had the drought continued another six months the expense of feeding would probably have been almost prohibitive.

RATE OF STOCKING TO PROVIDE FOR DROUGHT.

Using as a basis the amount of forage produced on the protected areas during the drought, the results in maintaining the condition of the forage comparable to the protected areas in pastures 5 and 10 under the system of grazing used there, and the difficulties encountered in carrying the stock through the drought on the reserve, it is possible to decide upon a guide for the proper rate of stocking during drought in future.

Considering 1915-16 as about the maximum average condition which can be expected for the yearlong or winter range of the reserve, or for similar range, the maximum stocking should not exceed the estimated average required per head in pastures 2 and 10 in 1915-16, or an average of 27 acres per cow for yearlong grazing, and should only be this heavy when it can be controlled so as to reduce grazing 30 to 50 per cent from average during the growing season—July to September, inclusive. The forage produced in 1916-17, the first years of drought, as shown by the protected areas, would not necessitate much reduction in grazing that year; but with the prospects of further dry years to follow, it is considered best to reduce grazing about 15 per cent the first year of drought and save the surplus grass for succeeding years. A summary of the estimated

carrying capacity of pastures 5 and 10 in 1917-18, the second year of drought, as given in Tables 11 and 12 shows an estimated reduction of about 35 per cent from maximum in an average year. From the difficulties encountered in 1917-18, however, it is believed that

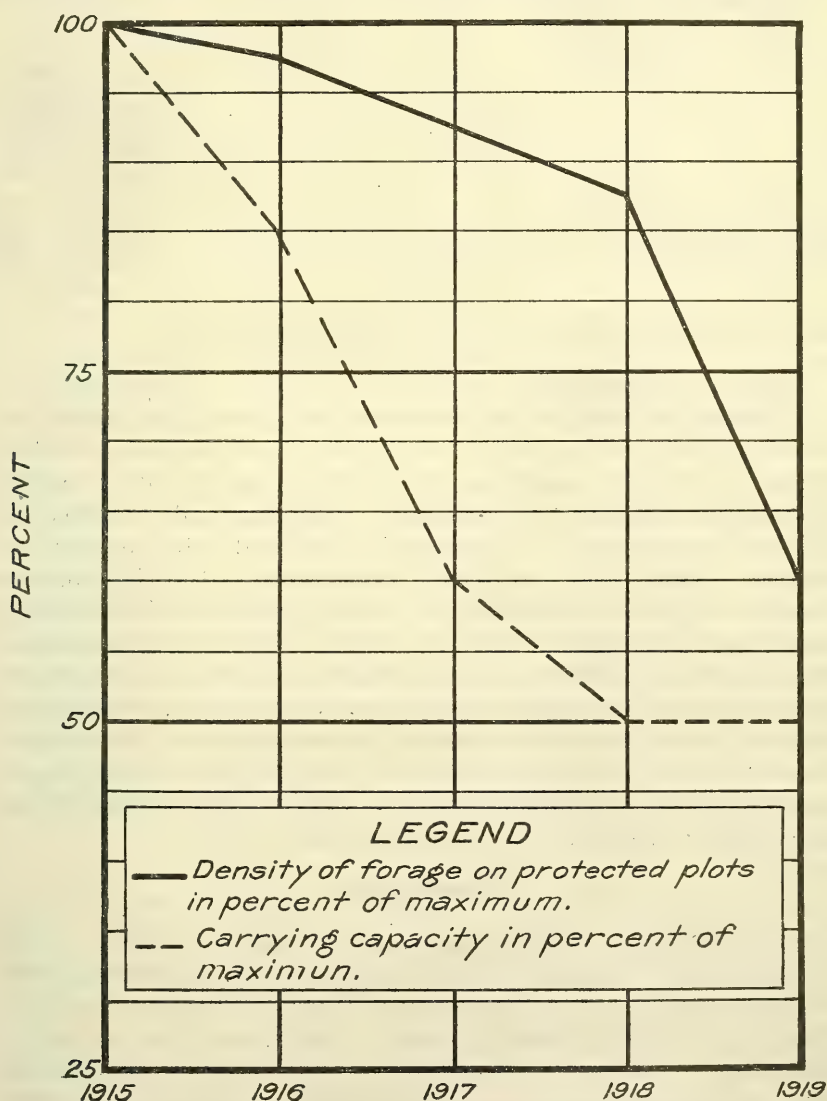


FIG. 8.—Estimated carrying capacity of grama-grass range in time of drought.

during the second year of drought there should be a reduction in number of stock grazed of at least 40 per cent from maximum estimated grazing capacity and a further reduction of 10 per cent in the third year.

The basis decided upon as a guide on the reserve in the future during drought, therefore, is shown in Table 14.

TABLE 14.—*Rate of stocking recommended for grama-grass range, Jornada Range Reserve, during period of drought as compared with maximum grazing capacity.*

Period.	Rate of stocking in acres per head for 365 days' grazing.	Rate of stocking in per cent of maximum grazing capacity.
Year before drought.....	27.0	100.0
First year of drought.....	32.2	85.0
Second year of drought.....	45.7	60.0
Third year of drought.....	54.0	50.0
Fourth year of drought.....	54.0	50.0

¹ This estimate is for the drought of 1916-1919. Should drought continue throughout the fourth year or longer, a greater reduction would be necessary depending upon existing conditions.

Intensity of grazing on this basis is shown in comparison with the changes in condition of representative grama-grass range protected against grazing prior to and throughout the drought which ended in 1919. In connection with figure 5, page 21, the probability of this curve (density of vegetation) being too high for 1917 and 1918 was pointed out. The points for 1915 and 1919, however, can be relied upon. Figure 8 shows a more rapid and greater total reduction in proposed intensity of grazing than in depreciation of range due to drought alone. The difference should make possible the maintenance of the range somewhere near the condition of protected areas. Just what further reduction in stock would be necessary in case of prolonged drought is problematical. It is hoped, however, that a maximum reduction of about 50 per cent and supplemental feeding will take care of the stock during droughts which may occur in the future on the range reserve.

SUMMER RANGE.

Tables 15 and 16 show grazing capacity data for pastures 13 and 1, respectively. Pasture 13 is the most nearly representative of the range suitable primarily for summer grazing, but was not so badly affected by drought, receiving more rainfall than any other part of the reserve. Pasture 1 was representative as to drought, although there is a large area of mesquite-sandhill and grama-grass types in addition to the summer range.

TABLE 15.—*Rate of stocking and estimated carrying capacity, Pasture 13, 1915 to 1919.*

[Area of pasture 17,001 acres.]

Period, July 1 to June 30.	Average acres per head for 365 days' grazing.	Estimated per cent of forage utilized.	Estimated grazing capacity acres per head for 365 days.
1915-16.....	42.3	100	42.3
1916-17.....	64.5	80	51.6
1917-18.....	65.1	90	58.6
1918-19.....	114.4	50	57.2

TABLE 16.—*Rate of stocking and estimated grazing capacity of Pasture 1, 1915 to 1919.*

[Area 74,714 acres.]

Period, July 1 to June 30.	Average acres per head for 365 days' grazing.	Estimated per cent of forage utilized.	Estimated grazing capacity acres per head for 365 days.
1915-16.....	48.6	100	48.6
1916-17.....	48.2	100	48.2
1917-18.....	85.3	100	85.3
1918-19.....	71.3	80	57.0

These tables show that the carrying capacity of the summer range has varied from 42.3 acres per head in good years to 85.3 acres per head in time of drought, a reduction of 50 per cent. Extent of grazing during the growing season does not affect this type materially, although the amount of forage produced and consequently grazing capacity are greatly influenced by precipitation. If the 1916-18 dry period is a fair measure of the possible severity of drought, and it probably is, the number of stock dependent on such range for summer grazing should be reduced approximately 50 per cent in the third dry year, with some reductions necessary the first and second years. This corresponds to the reductions recommended for the grama-grass range. It is believed that the reduction in stock during drought, as proposed in Table 14, will apply to both the grama-grass and tobosa-grass range and therefore to the Jornada Range Reserve as a unit or to other range units under similar management in southern New Mexico.

ADJUSTMENTS NECESSARY IN CATTLE MANAGEMENT.

The great reduction in the volume of forage produced during drought and its effect on the grazing capacity or percentage of stock grazed, and the impracticability of extensive feeding to meet the de-

mands of such a situation, make it seem obvious that the character and extent of livestock production in the section where these conditions prevail should be carefully adjusted to the supply of range forage as the primary source of feed. This is at least so until such time as agricultural development and economic conditions change in a way to supply other feeds in amount and at a price compared with the value of stock which make extensive feeding profitable.

The number of stock grazed must either be confined at all times to the number that the range will carry over periods of drought, or provision be made to reduce the number of stock when drought begins and increase them again with the improvement of range following drought. To limit the number of stock in good years to the number that can be carried over in drought would entail the loss of a great amount of forage, amounting in good years to as much as 50 per cent or more of the carrying capacity in normal years. The situation calls for an adjustment in the business that will permit obtaining the maximum use of the forage produced in good years, but at the same time will permit orderly reduction in the number of stock in time of drought without loss.

Using as a basis the data on the volume of range forage which may reasonably be expected annually over a period of years including a drought and the effect of this variation upon grazing capacity or percentage of stock grazed each year, as arrived at in the preceding chapters, it remains to decide upon the class of stock and their numbers and management annually and for a period of years including a drought.

SOUTHERN NEW MEXICO A CATTLE-BREEDING SECTION.

All stockmen may not agree that the ranges of southern New Mexico are essentially a cattle-breeding ground. The facts, however, appear to warrant this statement. One alternative would be to obtain steers at an early age and grow them to 2, 3, or 4 years of age for shipment to northern and middle western pastures and feed lots to be finished for beef. The difficulty of this practice is to obtain the steers. In times past large numbers were obtained from Mexico. As a future practice this has but doubtful possibilities, since it will be some time before Mexico has any certain surplus of steers for export.

The best permanent interests of the section will be served by developing the industry to produce calves and steers and surplus cows, at least as long as present conditions prevail. In working out livestock production on this basis obviously the foundation is the breeding herd, with variation in the number and ages of steers to conform to variation in supply of range forage and market conditions.

BREEDING HERD SHOULD BE LIMITED TO GRAZING CAPACITY OF THE RANGE DURING DROUGHT.

The tendency has been to increase the breeding herd during good years to the limit of range capacity and in many instances beyond this limit. When drought came on, anything for which there was a market was sold, and thus years of effort in improving the herd were lost, at least in part, while losses from starvation were excessive. The increasing cost of producing the individual animal and the growing importance of improving the average grade of stock, to meet the demand from the feed lots, both argue against continuation of this old practice. The alternative is to limit the breeding stock to the number that can be taken care of during periods of drought.

BREEDING HERD ON THE JORNADA RANGE RESERVE.

In attacking this problem on the Jornada Range Reserve the original plan was to keep two-thirds of the normal grazing capacity of the entire range for breeding cows, young heifers to replace culls from the breeding herd, bulls, saddle horses, and a few brood mares. Table 17 shows the number of these classes of stock carried each year through the period 1915 to 1919 including a drought, the percentage of the range used for each class of stock, and the amount of forage crop produced each year in percentage of the 1915-16 crop, which is considered about maximum for the reserve.

TABLE 17.—*Number by classes of stock making up permanent herd on Jornada Range Reserve, each class in percentage of total grazing capacity of the reserve in 1915-16, and estimated forage production in terms of 1915-16 crop.*

Year.	Cows of calving age.		Bulls.		Heifers 1 year old and up not yet placed in breeding herd.		Horses.		Total in percentage of total grazing capacity, 1915-16.	Estimated forage crop production, percentage of 1915-16, production. ¹
	Number.	Percentage of total carrying capacity, 1915-16.	Number.	Percentage of total carrying capacity, 1915-16.	Number.	Percentage of total carrying capacity, 1915-16.	Number.	Percentage of total carrying capacity, 1915-16.		
1915-16.....	1,950	41.75	80	1.71	695	14.87	120	2.56	60.89	100
1916-17.....	2,022	43.27	80	1.71	751	16.07	140	3.00	64.05	81
1917-18.....	1,986	42.49	80	1.71	892	19.08	180	3.85	67.13	54
1918-19 ²									49.42	64

¹ The 1915-16 range is considered near maximum condition and therefore is used as the basis of comparison. The amount of forage produced in other years was arrived at by careful estimates of the amount produced on the reserve as a whole checked by quadrat measurements and number of stock the range was actually able to support.

² During the grazing year ending June 30, 1919, the various herds were disorganized by removal to other range for part of the year. However, an average of 2,310 head of stock were grazed during the year.

The last two columns of Table 17 show, first, that only in 1917-18 did the breeding herd, including other permanent stock, exceed two-

thirds of the grazing capacity in 1915-16, which was near maximum; and second, that only in the same year, 1917-18, did the estimated range forage production fall materially below approximately two-thirds of production in 1915-16, and even then the excess was less than 1 per cent. The original plan, however, was to reduce other stock so as to keep total grazing well within forage production. Table 18 shows what was actually done.

TABLE 18.—*Permanent stock, steers, and total, compared with forage production by years.*

Year.	Perma- nent stock in percent- age of total grazing capacity, 1915-16.	Steers.		Total in percent- age of grazing capacity, 1915-16.	Forage produc- tion in percent- age of 1915-16.
		Number.	Percent- age of grazing capacity, 1915-16.		
1915-16.....	60.89	1,542	32.99	93.88	100
1916-17.....	64.05	831	17.78	81.83	81
1917-18.....	67.13	477	10.20	77.33	54
1918-19.....	49.42	None.		49.42	64

The last two columns of Table 18 show that the total number of stock was slightly in excess of the forage production in 1916-17, the first dry year, and 43.2 per cent in excess of estimated forage production in 1917-18.

In disposing of steers the original plan was followed, but not soon enough. In the fall of 1915 it was evident that there would be considerable forage not needed by the permanent herd. Additional yearling steers were purchased and held over and sold in the spring of 1916 at a fair profit. Although in 1916 the prospect for surplus forage was not so good, it still appeared that there would be more range than needed for the permanent herd. The natural increase of steers under 2 years old, about 750 head, was held over, but only a few additional steers were purchased. Most of these steers were sold in the spring of 1917. After the growing season of 1917 it was evident that there would be a shortage of range forage for the permanent herd, and consequently all steers down to calves 4 months old were sold. Removing the steers late in the fall, however, and holding over a few surplus cows amounted to an average of 477 head of this surplus stock during the grazing year, July 1, 1917, to June 30, 1918.

Had the steers been sold in the spring of 1917 or earlier instead of holding them over until fall, much worry would have been avoided and the cost of supplemental feeding and losses would probably have been reduced. As it was, supplemental feeding, as given in Table 19, was considered advisable.

TABLE 19.—*Records of supplemental feeding to cows and heifers in breeding herd.*

Year.	Number stock fed.	Per cent of breeding cows.	Character and amount of feed.	Total cost of feed and feeding.	Cost per head.	Cost per head for entire herd.
1915-16.....	445	2.3	32,600 pounds cottonseed cake..	\$652.00	\$1.47	\$0.33
1916-17.....	420	2.0	39,470 pounds cottonseed cake..	1,051.69	2.50	.52
1917-18.....	11,769	89.0	171,016 pounds cottonseed cake..	8,747.36	4.95	4.40
1918-19 ³			(Pasturage, 353 tons soapweed ² .)			

¹ Includes only cows and heifers in breeding herd; bulls, calves, and young heifers not included.

² Pasturage for 215 cows and young calves for about three months, November, December, and January, \$2,304.71.

³ No feeding.

Even in good years the feeding of cottonseed cake or other concentrated feeds in small amount to the breeding stock to keep losses at a minimum and the stock in condition to produce a good calf crop is considered good business. The feeding in 1915-16 and in 1916-17 was for this purpose rather than because of lack of range forage. Feeding in 1917-18, however, was largely a necessity to get the stock through in any condition. Much heavier feeding would have been necessary to have maintained calf crop and losses at approximately what they were in other years. The losses were extremely low compared with either the average for this section over a period of years or the average for the drought, but were 3.5 per cent as compared with 1.7 per cent average for 1915-16-17 on the reserve. The calf crop in 1919 was 43 per cent as compared with 64.7 per cent average for 1915 to 1917 on the reserve. Further, the overstocked condition resulted in marked injury to pasture 2, the main grama-grass pasture of the reserve, and the possibility of heavier loss was too great. Had the drought continued another year with both stock and range in poor condition and surplus forage all used the situation would have been serious.

The \$4.40 per head cost of supplemental feeding in 1917-18 for breeding stock is not considered a serious matter, provided losses are kept down to about what they were for the reserve in 1915 to 1917 and the calf crop up to about what it was for that period. To have accomplished this in 1917-18, however, a material reduction in stock would have been necessary after the critical period arrived. The difficulty of selling surplus stock in poor condition at that time without a heavy sacrifice emphasizes the necessity for reducing the herd in advance.

The fact that forage production at the worst of the drought was estimated at only 54 per cent of what it was in 1915-16 over the whole reserve and only 60 per cent on the areas protected from grazing, and the probable difficulty of getting rid of all but breeding stock at the right time, lead to the conclusion that instead of using

two-thirds of the maximum grazing capacity as the basis of the permanent breeding herd 50 per cent should be used in future. This percentage, about 2,000 head,¹² will be made up almost entirely of cows of breeding age, bulls, saddle and work stock, and perhaps about 3 per cent of heifers selected to replace loss and such cows as must be removed from the herd on account of injury or other causes.

With this number of stock and percentage of total stock for the breeding herd combined with the data contained in figure 8, figure 9 has been prepared to show the breeding herd, the stock other than breeding stock, and the total stock in relation to maximum condition of the grama-grass range as shown by protected areas for the respective years.

Figure 9 applies to the reserve for the period 1915 to 1919, inclusive. This covers conditions in the more nearly average year of 1915, which was about five years after the drought of 1908-1910 had broken and through the drought of 1916-1918. From data and observations as to conditions from 1910 to 1915 and from the precipitation records shown in figures 2 and 3 there is probability at least that the curve for total grazing capacity for 1920 to 1923, inclusive, will be approximately the reverse of the grazing-capacity curve shown in figure 9 for 1915 to 1918, inclusive. If the climate continues in cycles as in the past there will probably be another drought about 1924. The future management of the Jornada Range Reserve will be based upon these two assumptions. The breeding herd came through the drought of 1916-1918 with nearly enough good young breeding cows for the permanent breeding herd recommended. The question now is to decide what class of stock should be kept to use the gradually increasing surplus range forage up to 1924, or up to the next drought, and at what age to dispose of the excess stock produced.

SURPLUS STOCK SHOULD VARY WITH RANGE FORAGE PRODUCTION AND WITH THE MARKET.

As shown in figures 8 and 9, after the permanent breeding herd recommended is taken care of there will be surplus forage varying from nothing at the worst of the expected drought to 50 per cent of the total for a given range unit about 3 to 5 years after a drought is broken, and possibly more in a period of exceptionally good years. This, of course, assumes that the range is to be properly managed so that it will recover.

¹² Originally the pasture in the San Andres Mountains was included as part of the area to be used by breeding and other permanent stock of the reserve in time of drought, the surplus forage being used by horses and extra stock in good years. Because of the extremely rough topography and rocky surface, poor success was obtained in trying to use this area by stock accustomed to the level ground where there were no rocks. Consequently the plan for the future is to use this area for horses and steers or other stock that are placed in the mountains as yearlings and left there long enough to become accustomed to the rough country, and not as part of the breeding area proper.

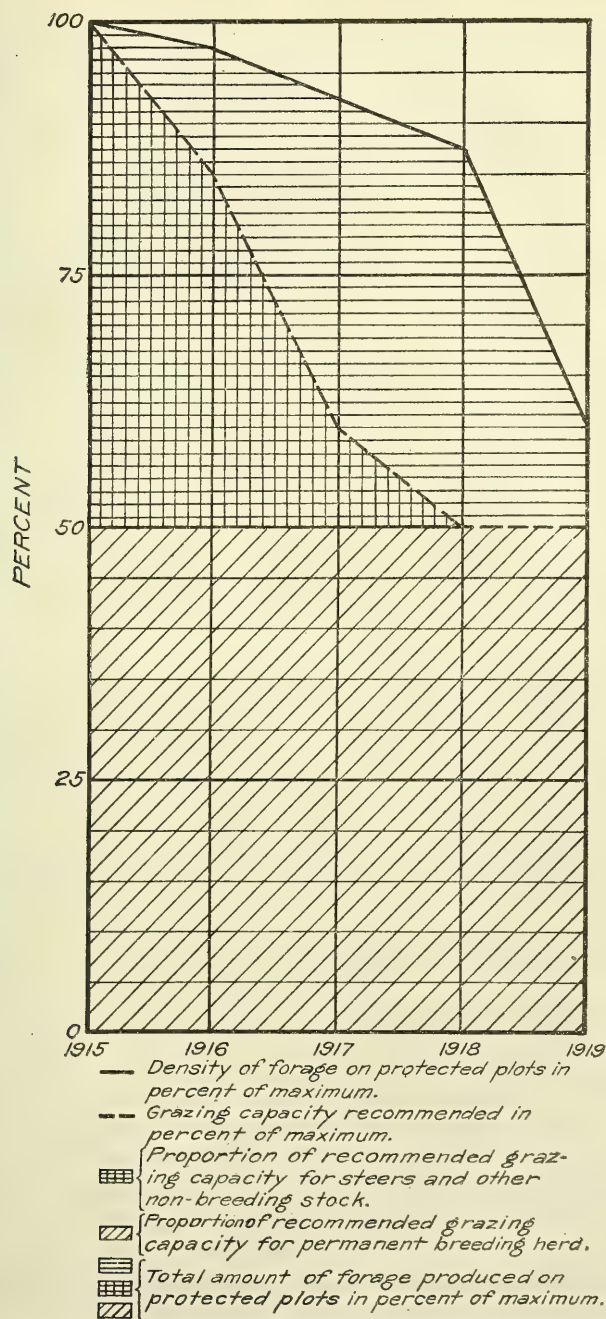


FIG. 9.—Amount of breeding stock and nonbreeding stock recommended in proportion to forage production on protected plots over a period of years.

There are several possibilities for profitable use of this surplus forage. First, provision must be made for reserving enough heifers from the natural increase of the breeding herd to provide for improving the breeding herd by culling and replacement. The breeding herd recommended provides about 3 per cent of heifers to replace loss and a small additional percentage of injured and unthrifty cows, but does not provide for heavy culling to improve the grade of the herd or to get rid of old cows. Stockmen will probably differ as to the best policy to pursue. The Jornada breeding herd was carefully culled over in 1919, and it is not probable that heavy culling will again be undertaken for several years. Before another drought, however, or about 1924 if no drought is evident at that time, about 50 per cent of the present breeding herd should be replaced by heifers selected from the natural increase. This replacement will serve the double purpose of improving the grade and providing a herd made up of young cows best able to withstand the hardships of drought. To get the best results the heifers for replacement should be selected from calf crops in years when forage conditions are favorable to development of young stock, probably from those before 1922, so that they will be at least two years old when put into the breeding herd.

Whether additional heifers will be held over will depend upon the demand and market for young breeding stock as compared with demand and market price for steers. During the next few years there will probably be demand for heifers to build up herds greatly reduced during the drought. There is also the possibility of holding over some heifers in good years in addition to those necessary for replacement in the permanent breeding herd, to increase this herd temporarily and thus secure some additional calves in good years. Further total increase in stock should then be held down by selling young stock as calves. Increase in the breeding herd is dangerous, however, unless such increase will be disposed of before another drought. The actual time when the next dry spell may start, of course, can not definitely be foretold.

Prior to 1918 on the Jornada Range Reserve most of the heifers were held over as part of the breeding herd, because of the heavy culling of this herd to improve both grade and age. This was considered warranted in view of the rapid improvement desired, but even then losses would probably have been lighter and cost of feeding not so heavy in 1918 if plans had been made beforehand and part of the heifers disposed of each year during the drought.

There is usually demand for steers 1 year old or over at any time of the year. In the past the policy at the Jornada Reserve has been to use for steers most of the forage not needed by the breeding herd. This policy, instead of holding over heifers for sale, has been with-

out question in the past, however, because of the demand for heifers to replace culls in the breeding herd to improve both grade and age. These steers, while not in condition to go as feeders, have supplied a demand each year in the past to go to northern and middle western pastures and have always been handled at a profit. Producing feeder steers, as discussed later under feeding, may prove in the future to be good business, and if so the holding over of more steers rather than heifers may be advisable.

There is usually a good demand for well-bred calves at weaning time in the fall, and the sale of an entire calf crop is a possibility if the range is fully stocked and the market is not right for the surplus stock already being held.

The number of surplus stock, therefore, should be adjusted carefully to the available range forage not needed for the breeding herd, and the class of stock held to use this surplus forage will be governed by demand and market price for the different classes. Over a period of years the demand and price will probably be in favor of steers.

As in the past, the temptation will be to overstock before the range has fully recovered after drought and not to reduce the stock prior to the drought. This overstocking comes by holding all heifers to increase the breeding herd after drought and holding steers at least to 1 year old. In the Southwest this policy has been expensive in the past and will be equally or more expensive in future unless due care is taken to keep the total stock each year well within the probable grazing capacity of the range unit involved. Until data over a longer period are available, therefore, it is believed that the variation in forage crop and in numbers of stock by classes as presented in figure 9 should be followed as a guide in stocking southern New Mexico and similar range.

RANGE MANAGEMENT TO OBTAIN MAXIMUM FORAGE PRODUCTION AND PROPER USE.

Along with the study of the effects of time and degree of grazing upon the stand of forage on the range on the Jornada Range Reserve the plan has been to work out a system of grazing management and handling stock that will meet the growth requirements of the forage as determined, and at the same time meet the practical demands of the stock. To be both sound and practical such a plan must secure maximum utilization of the forage consistent with its growth requirements and have an adequate supply of range forage available for the stock at all times of the year. Management of grazing to have a range available during April, May, June, and the early part of July especially, is important in the Southwest, where these months are

usually dry, and stock, especially breeding cows, are in the most critical condition.

SEASONAL USE OF RANGE.

Where grama-grass or yearlong range and tobosa-grass or summer range occur together, as they do on the Jornada Range Reserve, management of the range is a comparatively simple matter.

The chief requirement of grama-grass range, to obtain revegetation and maintain it at its highest productivity, is protection or material reduction of grazing during the main growing season, July to September, inclusive. On the other hand, tobosa-grass or summer type of range, because of its growth habits and the character of the soil it occupies, does not suffer materially if grazed during the time it makes its main growth and must be grazed at this time if maximum utilization is to be secured. Division of these two classes of range, using the tobosa-grass and similar types during summer and fall, and holding the grama grass and similar types for use during the winter and spring, will serve the several-fold purpose of securing the full use of each, giving the grama-grass range the protection it requires during the growing season, and insuring a supply of winter and spring range for the stock.

Figure 1 shows how the various types of range have been divided into the two classes on the Jornada range reserve. Pastures 2, 3, 5, 10, and 12 are chiefly valuable for winter or yearlong range. Pastures 7, 8, 9, and 13 are best adapted to summer grazing. Pasture 1 contains both winter and summer range, but cattle are confined to the latter as much as possible by salting and closing waters on the former and later in the year opening these waters and salting on winter range. It was not always possible to put the fences directly upon the boundary between the two classes of range, especially where the types occurred more or less intermixed, without excessive fencing and water development, but the aim was to divide the range as nearly as practicable in this manner.

The plan has been to use pasture 13 as summer and fall range for a herd of 500 head and pasture 10 as winter range for this same herd each year. The more needy cows in pasture 10 during each spring were then separated and placed in pasture 7, a small reserve pasture. The larger breeding herd has been grazed in pasture 1 yearlong, with effort to confine the stock to the proper range at the proper season, except that all needy cows were separated and grazed in pasture 2, or one of the various smaller pastures where there was reserve feed, when their condition required it. Using pasture 1 as yearlong range with such control of stock as was possible by salting and riding has not been as satisfactory, however, as has been

division of winter and summer range by fencing for the 500-head herd. Future plans provide for the division of this pasture into summer and winter range. The benefits to the stock of this system of dividing the range and grazing it have been to carry them through the spring in much better condition and with less loss than on uncontrolled range, and it has had a desirable influence on the calf crop.

Where a range is not under control and is used yearlong, stock naturally graze the range more closely within the first mile or two of water first. Then later on, during winter and spring when the stock was poorest, they have to travel farthest from feed to water, this condition has often contributed to the heavy losses from starvation in the Southwest, especially where the distance between watering places is over 5 miles. This was largely overcome on the Jornada reserve by having a supply of fresh forage available near water for use by stock during the critical part of the year. Handling the cattle so that the more needy cows were placed on the winter range first gave them the further advantage of not having to compete with stronger stock. The latter were then left on the summer range until later to utilize completely any forage that still remained. The small winter-range pastures were held in reserve for use later in the spring by the most needy cows, especially cows to calve. Confining the breeding herd to less range during the main breeding season facilitates distribution of bulls among the cows, which is an important factor in increasing the calf crop. As is later pointed out, this has had material influence in securing larger calf crops in the special herd on the Jornada Range Reserve.

The principle is equally applicable on ranges where there is less pure summer range in proportion to the amount of winter or yearlong range available. Should a unit have a considerable amount of purely summer range but not enough to carry all the stock during the season, grazing may be planned so that such range may be fully used during the summer season and thereby reduce grazing on the winter range sufficiently to allow the 30 to 50 per cent decrease in stocking during the growing season for part of the winter or yearlong range each year. Following complete use of the summer range the stock should all be shifted to the yearlong range, with a sufficient amount held in reserve, for use by needy stock during winter and spring.

On a range unit that is all pure grama-grass or similar winter or yearlong range, the desired purpose may be obtained by use of the deferred and rotation system of grazing. Under this system the range is divided into three or more parts and grazing reduced at least 30 to 50 per cent of the yearlong rate during the growing season on one or more parts for two years in succession, or until the area

has had ample opportunity to recover to its proper stand of forage. As soon as one portion has been built up the same treatment should be given another part of the range and the process rotated so that the entire range will receive the benefits of the treatment every few years. Since part of the range is being more heavily grazed than the yearlong rate during the growing season, however, care should be exercised to see that this part is not injured before it receives an opportunity to be protected during the growing season.

DISTRIBUTION OF STOCK ON THE RANGE.

Full and even utilization of the forage, more especially on the larger subdivisions or units of range, is an important factor if best results are to be expected from a system of range management. On the Jornada Range Reserve, besides proper number and distribution of watering places, it has been found that other measures are very often necessary to secure the best results. When cattle are shifted from one part of a range to another there is a natural tendency for them to drift back toward their former range. Cattle are often slow to drift from the vicinity of water where grazing is quite close to another part of the pasture or range where there is more feed. Fencing in such instances may not be economical, but proper salting and range riding have been found of material benefit.

Distribution of water for stock.—Proper number and distribution of watering places are essential to avoid overstocking around water and secure full utilization of an entire range. It was pointed out¹³ that permanent watering places on the plains and mesa range of the Southwest should not be more than 5 miles apart wherever the carrying capacity of the range and the cost of water development will warrant. As the distance increases beyond 5 miles there will be rapid increase in local overgrazing near the water and in uneven utilization beyond 2½ miles from water, with poorer condition and heavier losses among stock. Plate IV, figures 1 and 2, shows the effects of too great distances between waterings on the range and of proper distances.

It was also pointed out¹³ that one permanent watering place to each 500 head of cattle is justified, and that where the conditions are favorable tanks should be constructed to catch flood waters to supplement the permanent watering places. Such tanks are of necessity limited to areas of suitable drainage, no tanks being possible on flat areas or those with extremely sandy soil. The southwest portion of the plains area of the Jornada reserve is well suited to tanking, and 14 surface tanks have been constructed to supplement the five perma-

¹³ Department of Agriculture Bulletin 588.

nent waters on this part of the reserve. These tanks aid materially in securing the use of more green feed and in making it possible to relieve the range near the permanent waters a portion of each year.

Riding and salting.—The economical limits of water distribution at best will be such that there may be considerable overstocking and consequent range depreciation around water. This can be materially reduced by handling the stock to get better distribution than will naturally result when cattle are allowed to follow their own inclinations.

The practice found most effective on the Jornada Range Reserve in getting better distribution of the stock when first moved to fresh range has been to divide the herd into small bunches and place each bunch at a different water. If all were turned loose at a single water they would be slow in working out to the other waters, and overgrazing of a portion of the range would result.

Salting is one of the most effective means of attracting stock to a range, and, if sufficiently salted, stock will be less likely to drift away. Stock should have all the salt they wish at all times and care should be exercised to see that the supply never becomes exhausted.

Salting only at or near those watering places on the range where it is desired that stock should go, and refraining from salting at or adjacent to water around which the forage is already fully grazed or where there is overgrazing, will aid materially in proper distribution of stock. Salting on areas away from water that for some reason or other cattle might not be using has been found effective in getting better use of such areas.

There are times, however, when locating cattle in small bunches at the various waters and even proper salting will not prevent excessive numbers of stock around a single water. This is often the case around home waters where stock are frequently worked or around waters where a large number of stock have become located. In such cases it may be necessary occasionally to close the water entirely until the stock have become accustomed to go elsewhere to drink. Riding after the cattle and keeping them turned back toward their proper range will also help in reducing the stocking on run-down range, and riding to see that no cattle suffer from lack of water is essential where a permanent water is temporarily closed up.

IMPROVEMENTS NECESSARY TO MEET INCREASE IN COST OF CATTLE PRODUCTION.

Stockmen of southern New Mexico and of other similar sections realize that increasing value of range and costs of feed, labor, and general supplies call for readjustment of production methods, especially for greater assurance against heavy losses. Any change, how-

ever, must bring increased benefits commensurate with or greater than the extra costs incident to the change. Such benefits may be in the form of greater stability with less hazard, which will improve the credit of the industry both as to obtaining of loans and rate of interest, or in the form of increased net returns on the total investment over a period of years. The two will usually go together.

The existing difficulty in obtaining long-time loans at low rate of interest on breeding stock is due in part to the uncertainty of drought and of heavy losses accompanying it. This makes difficult the holding of stock until market conditions are right for the purchase of equipment and feed for proper care of the stock. Greater stability in the business will lead to the establishment of range live stock, and especially breeding stock, as better credit for securing of longer-time loans at a lower rate of interest.

The most direct and greatest benefits, however, must come from improving the grade of stock, increasing the average percentage of calves, reducing the loss in all classes of stock, and increasing the growth of young stock. Determining the possibilities of improvement along these lines has been an important feature of the investigations at the Jornada Range Reserve since 1915. A report of progress was published in 1917.¹⁵ Data are now available through a period of drought.

IMPROVEMENT IN GRADE OF STOCK.

The plan of investigation and demonstration in improving the grade of stock provided for the selection and segregation of 500 of the best bred cows with Hereford characteristics, the improvement of the remainder of the herd by selling off-colored and poor-grade cows as rapidly as market conditions and natural increase in the breeding herd would warrant, and the purchase and use of pure-bred Hereford bulls. The purchase of pure-bred or better grade females was considered inadvisable. Twenty of the best bulls of each lot purchased were to be used with the selected 500 cows, to be replaced by better bulls as rapidly as additional purchases were made.

THE SPECIAL HERD OF 500 HEAD.

The special herd of 500 head was selected from the total of 1,950 cows of breeding age on the reserve during the summer of 1915. They were largely grade Herefords and generally showed the characteristics of the breed as indicated by the accompanying illustrations. (Pl. VII, fig. 2.) The ages in this herd varied from 3-year-old heifers to cows 10 to 12 years old. After selection the cows

¹⁵ Jardine, James T., and Hurt, L. C., Increased Cattle Production on Southwestern Ranges, U. S. Dept. Agr. Bul. 588, 1917.

were branded with a special brand for the herd, dehorned, and placed in a separate pasture.

In order to improve the grade of the herd as rapidly as possible the plan was to cull 10 to 15 per cent of the least desirable cows each year and replace them with good young heifers. Sixty-nine head were culled in the fall of 1917. These included a few cripples and two barren cows, while the rest were light-boned or otherwise lacking in desirable qualities or were past 11 years of age. They were replaced by an equal number of the best two and three year old heifers on the reserve, partly selected from the 1915 calf crop of this herd. It was thought best not to cull more heavily because of the possibility of decreasing the calf crop through introducing too many heifers. Sixty additional cows were culled in 1918, but no replacement was made at the time because of forage shortage and the prevalence of drought.

THE MAIN HERD.

After the selection of the 500 special cows, the remainder of the breeding herd consisted mainly of native or common stock and grades.¹⁶ (Pl. V, fig. 1.) No less than 600 head, however, were off-color and Mexico stock.¹⁷ Following the selection of the 500 head the main herd was worked over and 325 of the off-color and otherwise undesirable cows were cut out and marketed. In 1916, 101 head, and in 1917, 318 head of the least desirable cows were disposed of. These were replaced each year by 2-year-old heifers from the natural increase of the two herds. No culling was done in the fall of 1918 on account of interference with plans by an outbreak of scabies and the possible demand for breeding cows to restock ranges after the drought.

Average culling for the three years 1915 to 1917, inclusive, was at the rate of 12.6 head per hundred cows annually. By 1918, culling at this rate had resulted in marked improvement in grade and type of stock in the main breeding herd, aside from the improvement due to adding 2 and 3 year-old heifers. All the Mexico stock had been removed, as well as other off-colored, extremely light-boned, or otherwise undesirable cows. Approximately half of the herd consisted of white-faced stock, characteristically Hereford, the breed desired, and the rest were red and red-mottled-faced.

¹⁶ "Common" or "native" stock, as here used, is applied to offspring whose parents were of very poor breeding and uncertain origin. In "grade" one of the parents was pure bred and the other common or native; or both parents were well bred, so that offspring had over 50 per cent pure blood of a single breed.

¹⁷ "Mexico stock," the long-legged, long-faced, slim-bodied, various colored stock coming originally from Mexico and the one-time characteristic range animal for northern Mexico.

Most of the bulls in the herd in 1910 were grade Hereford and Shorthorn, with a few pure-bred bulls. All of the Shorthorns were disposed of by 1914. After 1910 more registered Herefords and a few grades were purchased, and since 1915 none but registered Herefords have been procured. A lot obtained in the fall of 1916 came from breeders in the Panhandle of Texas, but since that time all bulls for the reserve have been purchased from breeders in eastern and central Kansas. Effort has been made to buy slightly better bred bulls each year in order to continue improvement through bulls as well as in selection of cows.

The best bulls in each lot have been used with the special 500 herd. Plate VI shows a number of the bulls used in this herd in 1918. Twenty head from the first lot of 26 head purchased in Kansas were placed in the herd in 1917. In 1918 the best from a lot of 89 head were selected to replace the poorest ones in the 20 originally placed in the herd. Sixty-eight of the best bulls from a lot of 88 head purchased in 1919 were selected for use on the reserve during 1920, and the best of these will be used to replace a few of the poorest in the special herd.

RESULTS OF THE SELECTION OF COWS AND USE OF GOOD BULLS.

The results of the selection of breeding cows and the use of good bulls are shown in the offspring. Over 96 per cent of the calves from the special breeding herd since 1915 have had good Hereford color and markings and for the most part good backs, straight tops and underlines, and have shown good beef conformation in general. Yearlings and 2-year-old steers have sold for from \$2.50 to \$5 more per head than the average in that vicinity, partly on account of improvement in grade, and fewer steers have been rejected by buyers because of poor grade or lack of uniformity. Plate VII, figures 1 and 2, shows the changes in type and grade of steers turned off the reserve following the improved breeding methods.

The accompanying photograph of yearling heifers (Pl. VIII, fig. 2), most of which are offspring of the selected herd, shows the grade of animal that is being produced. These heifers at 15 to 16 months of age averaged 534 pounds in weight before watering and after they had been off of feed for 24 hours. They showed much heavier bone, deeper bodies, wider backs, better developed loin and hind quarters than the average of either original herd, and approached more nearly the class of stock desired by the feeder.

RESELECTION OF HERDS IN 1919.

The net results from the work in improving the breeding stock from 1915 to 1919, especially the results from the special herd of 500 head, were so encouraging that during the summer of 1919,



F-22689-A

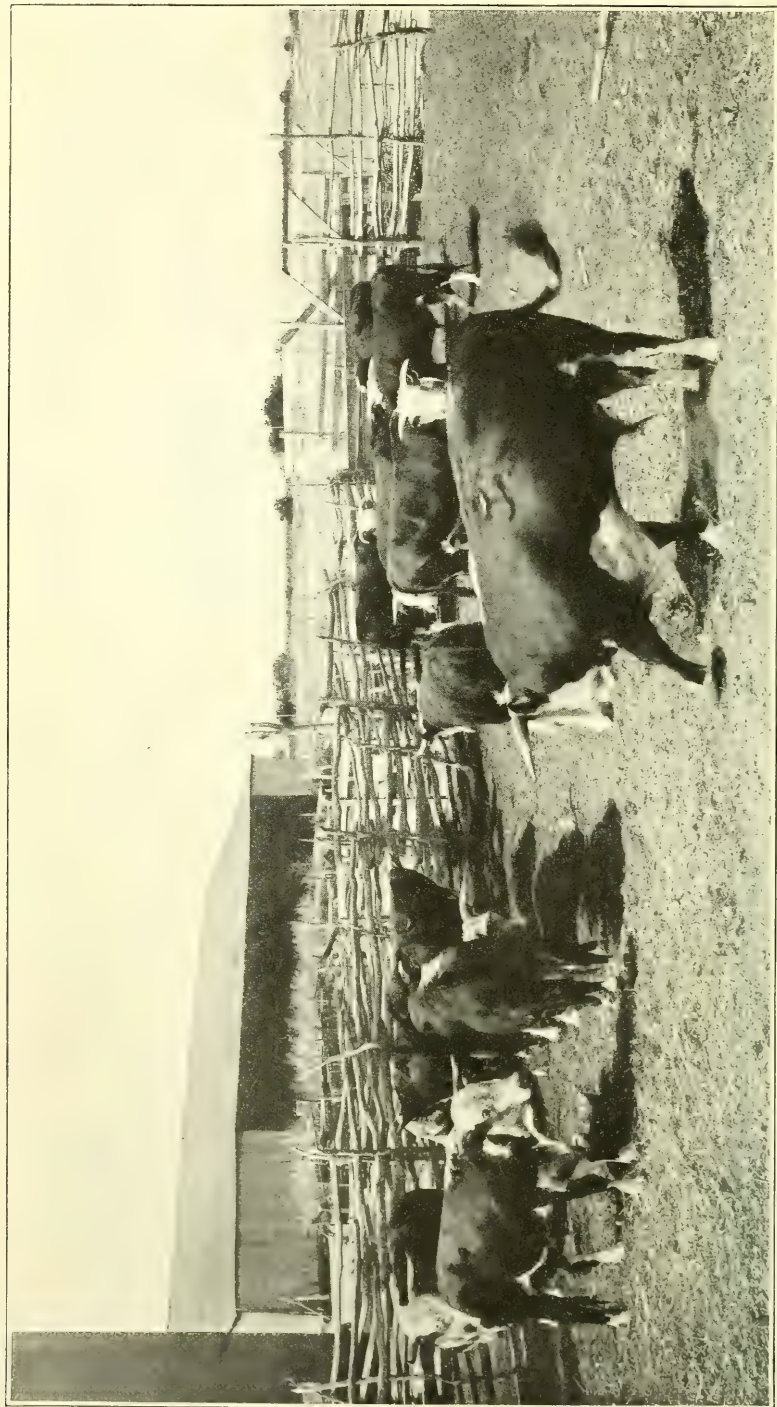
FIG. 1.—AN AVERAGE LOT OF THE BREEDING HERD ON THE JORNADA RANGE RESERVE IN 1915 BEFORE SPECIAL EFFORT HAD BEEN MADE TO IMPROVE THE GRADE OF STOCK.

The herd at that time was characterized by many light-boned and off-color cows.



F-36761-A

FIG. 2.—PART OF THE 500-HEAD HERD OF COWS SELECTED FROM THE MAIN HERD OF APPROXIMATELY 2,000 HEAD ON THE JORNADA RANGE RESERVE IN 1915 FOR SPECIAL BREEDING TESTS.



F-37735-A

PURE BRED HEREFORD BULLS PURCHASED FOR USE IN IMPROVING THE AVERAGE GRADE OF STOCK ON THE JORNADA RANGE RESERVE.
GOOD BULLS ARE THE BASIS FOR IMPROVING THE GRADE OF CATTLE ON THE RANGE.

following the drought, the cooperator, Mr. C. T. Turney, decided to make a careful selection of breeding stock for both herds. From a total of 3,458 head of breeding cows and excess yearlings and 2-year-old heifers which had accumulated, 1,750 of the best cows and heifers were selected as the total breeding herd for the reserve. Of these, 387 head 20 months old and up were selected for the special herd, and 95 head of the best yearling heifers for a special test in breeding. The 1,263 head remaining at that time constituted the main breeding herd.

The cows and heifers for the special herd were selected with the object of securing the best individuals from the standpoint of breeding, conformation, and Hereford markings, regardless of whether they were offspring from the special 500 herd or the main herd of the reserve. The exact number of cows and heifers selected from the two herds for the new special herd was as follows:

Cows retained from original 500 herd inclusive of re-	
placement -----	67 head=17.3 per cent
Heifers, offspring from the 500 herd-----	174 head=45.0 per cent
Heifers, offspring from the main herd of approxi-	
mately 1,200 head-----	146 head=37.7 per cent

The total heifer branding in the experimental herd during the years 1916 and 1917 was 354 head and in the main herd 836 head, so that 49.1 per cent of the calves from the former were selected, while only 17.4 per cent of the latter were chosen. This is approximately 3 to 1 in favor of the herd in which greatest effort had been made to improve the grade.

At the same time 95 of the yearling heifers were selected for a special test. The best individuals were chosen regardless of the herd they originated in. Out of the 95 head, 69 were from the 200 heifers branded in the 500 herd in 1918. The remaining 26 head were from 302 heifers branded in the main herd in 1918. The ratio of selection is approximately 4 to 1 in favor of the offspring of the selected 500 cows.

In comparison with the original 500 special herd, the cows in the reorganized herd of 387 head are all as good or better grade individuals than the best of the former herd. The young cows show heavier bone, better development of loin and hindquarters, and greater beef conformation in general. Uniformity in grade and color is especially striking.

The general herd of 1,263 head are all characteristically Hereford, comparing favorably with the original 500 herd. As compared to the original main herd, all indications of common blood have been eliminated, with a decided improvement in bone and beef conformation. The greatest single mark of improvement is the elimination of

all off-color stock and the consequent striking uniformity of color and markings.

It is planned to continue building up these two herds as rapidly as possible from the offspring to a total of approximately 2,000 head. The plan will be to replace the poorest individuals in both herds with the offspring from the special herd and the best offspring from the main herd, with minimum interference with the calf crop from the introduction of too many young cows in the breeding herd at any one time.

INCREASING CALF CROP.

Where live-stock production is managed primarily on a breeding basis, as recommended for southern New Mexico, the ratio of cows maintained over a period of years to calves produced to selling age is of the first importance. If the average calf crop is 50 per cent or less, as it frequently is in this locality, an increase of 5 calves from every 100 cows may mean a decrease of 10 per cent in the cost of producing the average calf to weaning age. Management requirements of the stock on southwestern ranges, to avoid drought, warrant such effort as will most economically secure the greatest number of calves possible.

In connection with a study of live-stock production in the 11 Western States during 1914, data relative to calf crop over a period of years were obtained from stockmen for all of the western States, including the Southwest.¹⁸

Table 20 shows, by States, the average number of calves for each hundred cows, as well as the number of bulls for each 100 cows, as given by the schedules from stockmen.

TABLE 20.—Average number of bulls for each 100 cows and average number of calves from each 100 cows.

State.	Bulls.	Calves.	State.	Bulls.	Calves.
Arizona.....	6	57	New Mexico.....	5	66
California.....	3.73	73.55	Oregon.....	4.04	75.74
Colorado.....	4.16	69.3	Utah.....	4	69
Idaho.....	4	75	Washington.....	3.72	79.48
Montana.....	3.44	75.8	Wyoming.....	5.52	73.2
Nevada.....	4	79			

The average calf crop for southern New Mexico over a period of years does not exceed 50 per cent.

Table 21 gives the records of calf crop each year in southern New Mexico, estimated in connection with the investigations at the Jornada Range Reserve since 1916, and similar data for the whole

¹⁸ Barnes, Will C., and Jardine, James T., Livestock Production in the Eleven Far Western Range States, U. S. Dept. Agr., Office of the Secretary, Report No. 110, Part II, 1916.

State since 1917, obtained from the Cattle Sanitary Board of New Mexico.

TABLE 21.—Average number of calves for each 100 cows.

Year.	Southern New Mexico.	Whole State.
1916.....	55	.....
1917.....	35	1 33
1918.....	25	30
1919.....	35	25
Average.....	37.5	29.1

¹ 50 per cent of usual calf crop.

The results obtained on the Jornada Range Reserve up to 1915 were no exception to the other ranges of New Mexico. The calf crop on the reserve in 1913 was approximately 48 calves per 100 cows; in 1914, 62; and in 1915, 52. The period 1913 to 1915 includes three good years, so that the average for the reserve prior to 1916, when a period of drought is included, did not, in all probability, reach above 50 calves per 100 cows.

Breeding stock on Arizona and New Mexico ranges are, for the most part, handled on the open range or in large pastures, making proper bull service difficult. Little or no effort has been made in the past to care for stock during the winter and spring, and cows very often go into the breeding season in poor condition. In the other States breeding stock are handled in smaller herds, thus facilitating bull service. Breeding stock are fed during winter and early spring and go into the breeding season in good condition. These differences in methods of handling stock in the Southwest and in other States are, no doubt, largely responsible for the yearly average of 16 calves less per hundred cows in Arizona, 23 less for the southern part of New Mexico, and 7 less for the whole State than the average for the other nine States.

CALF CROP ON THE JORNADA RANGE RESERVE SINCE 1915.

Investigations into the possibility of increasing the calf crop have been an important feature of the studies at the Jornada Range Reserve since 1915. The original plan was to study the comparative calf crop from a herd of approximately 1,500 cows run together, a herd of 500, and a herd of 42, all three under fence on the reserve, and the calf crop from range herds on similar range under prevailing open-range practice. The 500-head special herd and the 1,500-head herd were the same used in the general investigations, as well as in the demonstrations in improving the grade of stock, and have already been discussed under the latter heading. The large herd

consisted mainly of native stock from 2 to 12 years of age. The special herd was much the same in so far as age limits were concerned, but the cows were more nearly uniform grade Herefords. The 42 cows in the small herd were from 4 to 12 years of age, and were about the same as the special herd in grade. The drought in 1916 to 1918 interfered somewhat with the control of the separate herds, especially the herd of 42 head for which only one year's record is available. The results of calf crop obtained in the various herds on the Jornada Range Reserve and comparison with the estimated calf crop for outside range with average for the four-year period are shown in Table 22.

TABLE 22.—*Number of calves per hundred cows on open southern New Mexico range and on the Jornada Range Reserve.*

Year.	Outside range.	Jornada Range Reserve.			
		1,500-head herd.	500-head special herd.	42-head herd.	Average.
1916.....	55	69.2	81.0	.....	72.0
1917.....	35	52.7	68.2	.....	64.1
1918.....	25	50.8	80.0	97.6	58.8
1919.....	35	41.4	52.0	.....	43.7
Average.....	37.5	55.2	70.3	.....	59.6

The larger calf crops of the Jornada reserve, as shown in the table, are the results of the methods of handling the stock in practice. These involve condition of the cows and bulls, number and distribution of bulls among the cows, and the segregation of nonbreeding stock from the breeding herd.

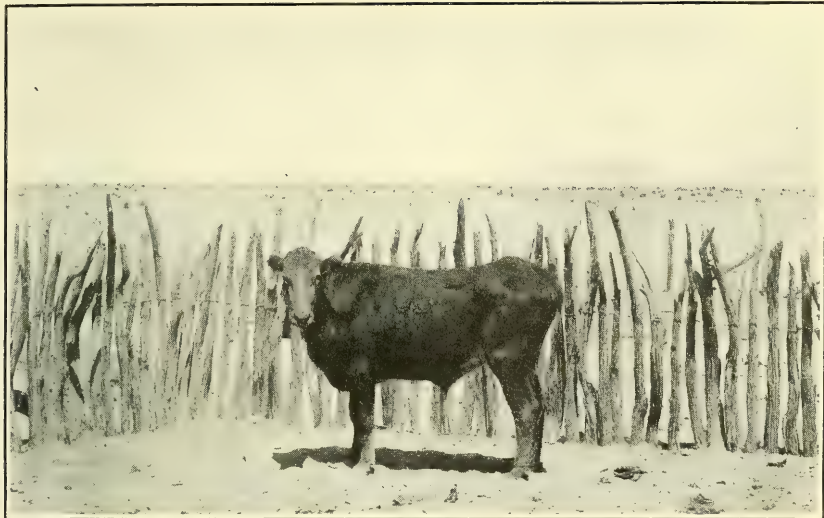
Condition of cows.—To insure the cows in the special herd being in thrifty condition for breeding and calving, grama-grass range was reserved for use by the herd during the winter and spring and supplemental feed was provided, as is shown in Table 23. In addition, the calves were weaned early, which gave the cows the advantage of being dry several months before the next calving time.

TABLE 23.—*Cottonseed cake fed and cost of feeding to cows in 500-head herd.*

July 1 to June 30—	Number of cows fed.	Percentage of total breeding cows.	Amount cottonseed cake.	Total cost, feed and feeding.	Cost per head.	Cost per head for entire herd.	Period of feeding.
			<i>Pounds.</i>				
1915-16.....	1 371	52	25,650	\$534.00	\$1.44	\$1.07	{ Feb. 1 to Apr. 26 June 6 to July 19 Dec. 9 to Sept. 7 Feb. 1 to June 15
1916-17.....	220	44	22,585	649.32	2.95	1.60	
1917-18.....	500	100	64,500	1,935.00	3.87	3.87	
1918-19 ²							

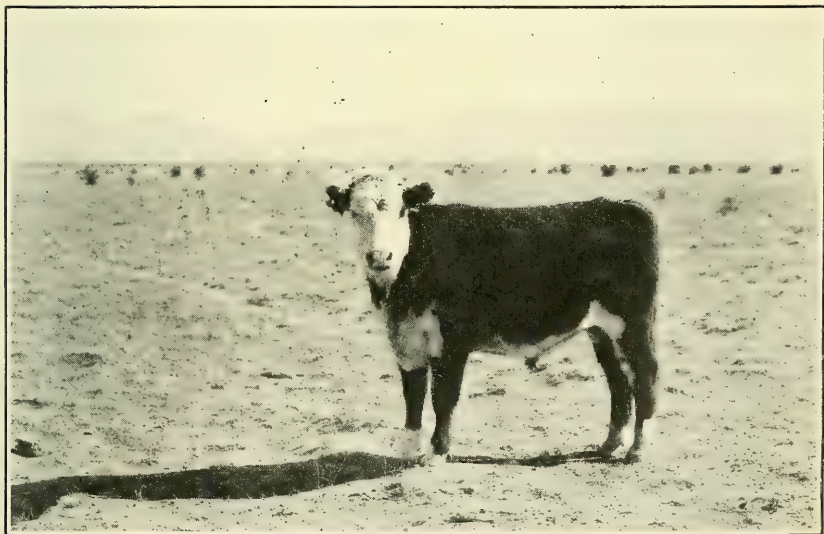
¹ Includes 20 bulls.

² No feeding.



F-37733-A

FIG. 1.—A 5-YEAR-OLD NATIVE STEER. THE OFFSPRING OF SCRUB PARENTS IS A POOR BEEF ANIMAL THAT BRINGS A POOR PRICE.



F-25901-A

FIG. 2.—A 2-YEAR-OLD GRADE HEREFORD STEER RAISED ON THE JORNADA RANGE RESERVE, THE RESULT OF EFFORT TO IMPROVE THE GRADE OF STOCK.

Note in general better beef characteristics as compared with Fig. 1. This type of animal is better suited to fattening for beef, and brings a higher price to the producer.



F-35690-A

FIG. 1.—A GROUP OF CULLS FROM THE MAIN HERD IN 1917.



F-42381-A

FIG. 2.—A GROUP OF YEARLING HEIFERS FROM THE 1918 CALF CROP, MAINLY FROM THE 500-HEAD HERD.

Disposing of the off color, poor grade, and otherwise undesirable cows and replacing them with the best 2-year-old heifers, the result of the use of pure-bred bulls, is the second step in the improvement of grade of cattle on the range.

As a result of the care given this herd, with but few exceptions the cows were in good, thrifty condition throughout the year. In the fall of 1916 some of the cows were not moved to winter range quite early enough and feeding them cottonseed cake was reduced early in 1917, so that they were somewhat under the condition they should have been in at that time. This is believed to account in part for the low calf crop in this herd in 1917. No feeding was considered necessary in the winter and spring of 1918-19, as the cows entered the winter in excellent shape and had an excess of good range forage during the whole period. With the exception of the fall and winter of 1916-17, 95 per cent of the cows were in good, thrifty condition at all times of the year.

The main herd on the reserve, of approximately 1,500 head, was given some special attention to maintain the cows in good physical condition, but not so much as was given the special herd. In the spring of 1916, 5.1 per cent of the cows were fed at the rate of 8 cents per head for the whole herd, 13.1 per cent at the rate of 32 cents per head in 1917, and 85.4 per cent at the rate of \$3.03 per head in 1918. Calves were weaned when from 8 to 10 months of age, except in 1917, when all calves down to 4 months of age were weaned in October. Range was reserved for only the poorest cows during the winter and spring of each year. The feeding and other care given the cows in this herd was primarily for the purpose of avoiding loss from starvation rather than of increasing the calf crop. The cows not fed, therefore, varied from those that were very poor but would probably pull through on the range without feeding until green grass came to dry cows that were in thrifty condition. Those that were not in thrifty condition included some not being fed as well as those on feed, and the number of unthrifty stock varied with the intensity of the drought.

The drought and lateness of the season in 1917 resulted in many of the cows in this herd not getting into condition to breed that year. The small amount of forage produced resulted further in a scarcity of range feed for the winter and spring, so that over 85 per cent of the cows had to be fed to keep them alive. The drought did not break until August of 1918. Therefore, a large percentage of the cows did not get into condition to breed for the 1919 calf crop before the severe winter set in. Although the drought was over before 1919, the calf crop that year was smaller than the previous year because the cows were in weaker condition and fewer were bred in 1918 than in 1917. The difference in condition of the cows in this herd as compared with the special herd probably accounts in a large measure for the difference in the calf crop in the two herds. However, the care and feed given the large herd to prevent loss from starvation had its advantage, since the calf crops obtained were

larger than in outside herds where little or no special attention was given to avoid loss from starvation.

Bulls, number and distribution.—Four bulls per 100 cows have been used in both these herds each year. All were strong, vigorous bulls, ranging from 2 to 7 years of age, and all those brought from other States were acclimated to the range for six to nine months before being turned into the herd. Each winter and spring all bulls not in good condition were fed cottonseed cake, with pasturage and other feed if necessary, to have them in what was considered good breeding condition for the main season. The amount of feed varied with the condition of each animal, but an average of $1\frac{1}{2}$ to 3 pounds of cottonseed cake per day was fed each bull for five or six months while on good dry pasturage.

The main breeding season occurs from late in July until October, and all the bulls were with the cows during this period. At other times of the year, however, a few of the more thrifty were left with the breeding herd. There is some question as to the advisability of leaving bulls with the cows yearlong, especially as more feed and better care in general is given the breeding herd; but there has been less question in the past, since stockmen operating under old methods felt that the growing seasons were too erratic to confine the breeding season to any one period of the year.

Except in 1918, special attention was given to distribution of bulls among the cows in the special herd. During the breeding season of the other years the 500 head of cows and 20 bulls were run by themselves in a pasture of 17,000 acres where there were four watering places. Besides being in this comparatively small pasture, a cowboy spent about three-fourths of his time during the main breeding season seeing to it that there was the proper number of bulls in proportion to the number of cows at each watering place.

The drought interfered with the regular procedure in handling this herd during the breeding season of 1918. The cows were moved to a brushy pasture of 74,714 acres, and no effort was made to keep the bulls distributed by riding after them. To this poor bull distribution is attributed the exceedingly low calf crop in this herd in 1919, for the cows were in excellent condition at all times and other factors were favorable.

The large herd was kept in a large, brushy pasture of 74,714 acres during the breeding season of each year except in 1918, when, owing to drought, they were removed to a much larger area of outside range. No effort was made at any time to keep bulls distributed by riding, and with 12 watering places in the pasture and more on the outside range, bull distribution was not as good as it might have been. Plate IX, figure 1, shows what may happen if no effort is made to keep bulls distributed. At that, however, there was some advantage in

having the cattle in the pasture as compared with outside range where stock were scattered over much larger areas with only four bulls per hundred cows. This poor bull distribution and difference in condition of the cows at critical times as compared to the special herd are mainly responsible for the difference in calf crop in the two herds.

The 42-head herd.—The drought interfered with the handling of the 42-head herd, but the results of one year have great significance in the possibilities of increasing the calf crop. The cows in this lot were run by themselves during the main breeding season of 1917 in a fairly large pasture with but one bull, but all came to a single watering place every day or every other day, so that the bull came in contact with all of them. The condition of these cows was about the same as in the 500-head herd, the 42 cows being fed during the winter as part of the special herd.

All but one of the 42 cows brought calves in 1918. While it is not safe to draw conclusions from a single trial, the results in this herd of cows indicated the possibility of securing large returns in calf crop when efficient bull service is assured and the cows are kept in good condition.

CALF PRODUCTION SUMMARY.

The calf crop for all the herds on the Jornada Range Reserve for the period 1916 to 1919, inclusive, shows an average of 22 calves more per 100 cows, or 60 per cent greater production than the average in herds on other range in the vicinity where little or no attention is paid to condition of breeding stock, distribution of bulls, and other influencing factors. The average in the special herd is 32.8 calves more per 100 cows, or 87 per cent bigger calf crop. The greatest variation is 80 calves per 100 cows in the special herd on the reserve in 1918, as compared with 25 calves for the same number of cows on outside range. These results are due mainly to provision of sufficient winter range and supplemental feeding during the critical period of the year and greater care in the distribution of the bulls. Comparisons of the results in different years in the various herds on the reserve further emphasizes the importance of these factors. The largest calf crop has been obtained each year in the special herd, with the exception of the one year's record for the 42-head herd. In the special herd, however, there was a marked drop in 1917, when the cows were allowed to get poor for a short period during the latter part of the breeding season of 1916. Again, in 1919, 28 calves less per 100 cows than the maximum average of 80.5 calves for 1916 and 1918 is thought to be due entirely to the lack of a sufficient number of bulls for the size of pasture the herd was in and the lack of riding to keep the bulls properly distributed during 1918.

Constant use of the better methods should result in a calf crop of not less than 70, or more nearly 80, calves per 100 cows each year on the ranges of the Southwest, instead of the usual 50 or 60 calves under present methods. So great an amount as \$3.87 per cow per year for feed and provision of adequate winter and spring range, as well as the small additional expense for proper bull distribution, are warranted when they affect calf crops so materially. Four bulls per 100 cows are insufficient unless stock are handled in small lots during the breeding season, and bull distribution is attended to by range riding on large ranges. With expensive, high-class bulls, fencing to control stock on small areas and riding to distribute bulls will doubtless be found more economical than the use of more bulls.

Segregation of breeding stock from nonbreeding stock is of importance in obtaining better bull service and should not be lost sight of in efforts to obtain more calves per 100 cows. In addition, it is probable that heifers under 20 months of age should not be bred under southwestern range conditions, as they usually skip the following year or require additional feed to prevent stunting. After a cow passes 11 or 12 years of age she usually begins to decline in productiveness and there is danger of heavy expense in feeding her through the spring, so that it is best to dispose of cows when they reach this age.

FUTURE PLANS FOR INCREASING THE CALF CROP ON THE JORNADA RANGE RESERVE.

The results to date on the Jornada Range Reserve justify continuing the methods of management and even intensifying them. In the future it is planned to increase feeding in the various herds to where all stock will be in better breeding condition, and also eventually to divide the range for the main herd so that the cows will be confined in a smaller area during the main breeding season, and in this way insure better bull service, as well as provide fresh range for winter. The herd of approximately 500 head will be handled much the same as previously, with more riding to keep bulls distributed. The herd of less than a hundred head will be continued in order to secure more conclusive data on the value of small herds.

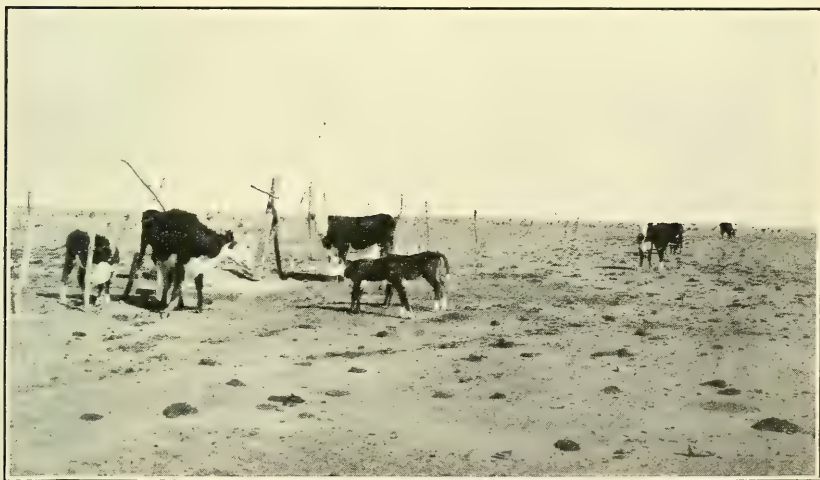
To determine the effect of breeding heifers to calve at 2 years of age, 95 yearling heifers were placed in a separate pasture and bred in 1919. Careful records will be made of the number of calves dropped, rate of growth of calves and heifers, and cost of feeding each year. They will be compared with a number of heifers not bred to calve until 3 years of age. Records for the two herds will be maintained long enough to obtain data as to the effect over a period of breeding heifers to calve at 2 years, compared to breeding them to calve at 3 years of age.



F-35687-A

FIG. 1.—SEVEN BULLS AT A SINGLE WATERING PLACE WITH ONLY 45 COWS. THIS ILLUSTRATES WHAT MAY HAPPEN IF MEASURES ARE NOT TAKEN TO KEEP BULLS DISTRIBUTED ON THE RANGE.

Good results may be obtained with 1 bull per 25 cows on level range if bulls are kept well distributed by riders.



F-45573-A

FIG. 2.—COWS, AND ESPECIALLY HEIFERS WITH YOUNG CALVES, LIKE THESE, CAN PROFITABLY BE FED A SMALL AMOUNT OF COTTONSEED-CAKE DURING THE SPRING BEFORE GREEN FEED OCCURS IN ORDER TO MAINTAIN MILK FLOW AND HAVE THE COW IN CONDITION TO BREED AND BRING A CALF THE FOLLOWING YEAR.



F-152750

FIG. 1.—FEEDING EARLY WEANED CALVES A SMALL AMOUNT OF CONCENTRATED FEED TO SUPPLEMENT THE RANGE FORAGE WILL MAINTAIN THEM IN BETTER CONDITION THAN IF THEY FOLLOW THE COW THROUGH THE WINTER.

There is less danger of loss among the cows and they will be in better condition to calve the next year.



F-37743-A

FIG. 2.—FEEDING CHOPPED SOAPWEED WITH COTTONSEED MEAL TO POOR STOCK ON THE VERGE OF STARVATION IN TIME OF DROUGHT.

When drought is prolonged and the reserve supply of range is nearing exhaustion, feeding of some roughage may be advisable. Soapweed (*Yucca elata*) is of value as emergency feed over large areas of the Southwest.

DECREASING LOSSES OF CATTLE.

The average annual losses of range cattle in New Mexico for the entire State for a series of years are approximately 7.3 per cent;¹⁹ for southern New Mexico, about 10 per cent. The New Mexico Cattle Sanitary Board²⁰ estimated the total loss of cattle in New Mexico during the drought of 1916–1918 and the hard winter of 1918–19 as 25 per cent of all cattle in the State, “the heaviest loss on record in a similar period.” This loss was in spite of heavier shipments of cattle from the State during 1917 and 1918 than for any two years previous. Losses for range similar to the Jornada reserve and in the same locality are estimated at 12 per cent in 1916, 15 per cent in 1917, and 35 per cent in 1918. Analysis of these losses will show that they are due mainly to starvation, directly or indirectly, disease, poisonous plants, and predatory animals—all more or less preventable. Obviously, reduction of the heavy losses on southern New Mexico and similar range is a necessity if live-stock production is going to be profitable under increased value of stock and range, large expenditures for range improvements, and increased labor costs. The problem of reducing losses has been attacked vigorously within limits of economy at the Jornada Range Reserve and the results are considered exceptionally encouraging, considering the large unit under management and the many problems encountered.

REDUCTION IN LOSS FROM STARVATION.

Starvation due to forage shortage, especially in time of drought, has been the main cause of losses among cattle on the Southwestern ranges in the past. As the forage supply on range is reduced in amount or becomes low in nutritive value during winter and spring before the rainy season begins, cattle, especially breeding cows, slowly lose flesh until they become so emaciated that they very often die. In their weakened state they often get stuck in bog holes or die calving, and all such losses are indirectly chargeable to starvation.

Occasionally, but very rarely except in the high mountain country, heavy snows may occur that cause injury to stock. Sometimes losses are caused by stock thirsting for water, when well equipment breaks down or springs or water holes go dry unexpectedly. Losses from lack of water usually indicate failure to keep equipment in good shape, to move cattle before the water holes dry up, or poor

¹⁹ Barnes, Will C., and Jardine, James T., *Livestock Production in the Eleven Far Western Range States*, U. S. Dept. of Agr., Office of the Secretary, Report 110, Part II, 1916.

²⁰ From extracts from Report of Secretary of the New Mexico Cattle Sanitary Board for year ending Dec. 1, 1919, to the Governor of New Mexico, printed in *El Paso Livestock Journal*, Mar. 1, 1920.

business foresight in not keeping a supply of water ahead of the daily requirement for use in an emergency.

Adjusting livestock production to the amount of forage produced over a period of years, as already discussed in preceding chapters, is expected to guard against the serious losses in time of extended drought. Within each year, however, from February or March to the beginning of the summer rains, is a period when there is great danger of loss from starvation. The available dry forage is low in nutritive value and the point of full utilization of the year's supply is being neared. Stock are normally in their poorest condition at this time of the year. In any herd on a fully stocked range there will always be a number of unthrifty cows among which losses will be heavy unless steps are taken to prevent it. Measures to prevent such losses are essential in addition to the plan for maintaining the permanent herd over a period of years, and constitute a secondary step in the whole plan to guard against losses from starvation. The principal measures taken to avoid loss from starvation on the Jornada Range Reserve have been reserving a supply of range forage for use by needy stock during the critical period of the year, proper distribution of water, early weaning of calves, supplemental feeding, and care in handling stock.

Reserved range feed.—The first step in providing for the critical period of the year has been to reserve a sufficient portion of range that is suitable for winter use for poor stock during the period January to July, as previously stated. Pastures 3 and 8 and part of pasture 7, all of which are principally grama grass and browse range, are held until winter and then used by poor stock from the main breeding herd. Pasture 2 is held for use by the main breeding herd in time of drought, and also for needy cows in this herd during spring. The animals in the large pasture are watched during winter and spring, and needy ones transferred to the small pastures where there is better forage. In the springs of 1916 and 1917 about 4 per cent of the cows in the main herd were transferred to these pastures. During the same period in 1918, the worst of the drought, these pastures were utilized for carrying the poorest stock. Having this supply of reserve forage available for use by the poorest stock played an important part in reducing losses in this herd.

The special herd on the reserve is provided for in pasture 13 during summer and fall. Beginning in early fall, the cows were carefully watched, and as soon as one began to get poor she was transferred to the winter range in pastures 10 or 7. This gave the poor cows the advantage of having fresh range and shorter distance to travel to water, which avoided much of the danger of loss. Complete utilization of the summer range by the stronger cattle was then obtained.

Water development.—Proper number and distribution of watering places plays an important part in keeping cattle in condition that will prevent losses. Naturally, where the distance between waters is great the feed near water is utilized first; then, later on, when the stock are poorest, they are compelled to travel great distances from water to feed, so that much time and energy are wasted. Losses on the outside range adjoining the reserve on the west, where watering places are 7 to 12 miles apart, were heavy in 1916, 1917, and 1918, largely on account of the weak stock having to travel so far from water to feed. As they grew weaker they were unable to travel out to where feed was good, and soon became so weak that they died. Having the watering places 5 miles or less apart will secure more even utilization of the range and weak stock will not have to travel so far to water.

Early weaning and feeding of calves.—Obviously, a cow will not do as well on the range when she is suckling a calf as when she has only herself to provide for. Weaning calves as soon as they are old enough, therefore, should be a decided advantage in maintaining cows in better condition on the range.

The practice on the Jornada Range Reserve in the average year has been to wean the calves during early winter when they are from 6 to 10 months of age. Plate X, figure 1, shows a number of calves on feed. In 1917, during the drought, all calves down to 4 months of age were weaned in October. When the calves were weaned the cows were turned back on the range, and fewer of them required feed or additional care than would otherwise have been necessary.

Early weaning of calves, even down to 4 months of age, has been made possible by feeding. Ordinarily, calves are weaned at 6 to 10 months of age. The earlier weaning has been limited to calves from a small percentage of cows, except in 1917. The number of calves fed, the amount and character of feed, and cost of feeding are given in Table 24.

TABLE 24.—*Number of calves fed, character and amount of feed, and cost of feeding.*

Year.	Number of calves fed.	Character and amount of feed.	Cost of feed and feeding.	Cost per head.
1916.....	1 700	37.2 tons cottonseed cake.....	\$1,722.10	\$2.56
		4.5 tons alfalfa.....	72.50	
1917.....	1 746	52.5 tons cottonseed cake.....	3,018.01	4.71
		69.5 tons ensilage.....	495.50	
		488 tons ensilage.....	3,466.00	9.14
1918.....	873	48.9 tons cottonseed meal.....	2,935.00	
		Valley pasturage.....	1,577.00	

¹ Includes half heifers and half steers.

The feeding of cottonseed cake to older calves in 1916 and 1917 was largely to prevent them from becoming stunted. Although they

did not make much growth from the time of weaning until green grass came the next spring, the small amount of cottonseed cake kept them in condition to respond readily when green feed came and prevented loss from weakness or starvation.

Calves under 6 months of age were fed corn and cane ensilage and cottonseed meal at the rate of 14 pounds of ensilage and three-fourths pound of meal per day. The extra feed was given the young calves to avoid the danger of stunting by leaving them on the range when weaned so young. The feeding of cottonseed cake only would not have been sufficient to prevent stunting. This feeding cost an average of \$9.14 per head in the fall and winter of 1917-18.

There is little question that feeding at the rate of \$2.56 per head or even \$4.71 is a good business investment, as was apparent in the sales of a part of the steer calves fed. In May, 1916, 100 head of long yearlings from the 350 steers out of the total of 700 heifers and steers weaned early in the previous winter and fed, were placed with the two-year-old steers and sold at regular two-year-old prices. At that time there was \$10 difference between the prices of a yearling and a two-year-old steer. In the spring of 1917, about 40 head were sold in the same manner, and 100 head were sold at two-year-old prices in the fall of 1917 when 18 months old. However, a part of this is also to be attributed to improvement of grade. Heifer calves, fed, made similar gain, showing the advantage to the calf of feed and extra care. Even so great an expenditure as \$9.14 per head in 1917-18 is not thought unwarranted when everything is considered. The calves fed were all heifers, and no sales were made, but they made normal gain and were up to the average weight for yearlings in June, 1918, while calves that followed the cows on the range were 25 per cent underweight at that date. A great advantage is given a cow when she is allowed the benefit of being dry several months previous to and during the most critical part of the year, and no small part of the success in keeping down the losses on the Jornada Range Reserve since 1915 is attributed directly to early weaning of the calves.

Supplemental feeding.—In any herd, no matter how much dry winter forage is available, there will always be at least a few unthrifty cows that may be lost if left to shift for themselves on the range. There might also be times when reserve forage or other measures may be insufficient to meet the demands for keeping down losses. Under these circumstances the use of supplemental feeding, in so far as it is economical, will assist in keeping down loss.

Feeding of cottonseed cake to poor cows.—When cows have become very poor and weak and the dry winter forage is too low in nutritive value to save them from starvation, a small amount of concentrated feed to supplement the range forage will make a better balanced

maintenance ration. Cottonseed cake has been used to supplement the range forage each year on the Jornada Range Reserve.

Table 25 shows the actual number and per cent of total herd, amount of cottonseed cake fed to supplement range forage, and cost of feeding, for the main breeding herd of approximately 1,500 head on the Jornada Range Reserve, 1915 to 1918.

TABLE 25.—Records of supplemental feeding of cottonseed cake with range forage to cows from the main herd of approximately 1,500 head.

Year.	Number cows fed.	Per cent of cows fed.	Amount cottonseed cake.	Total cost of feed and feeding.	Cost per head fed.	Cost per head entire herd.	Period of feeding.
			<i>Pounds.</i>				
1915-16.....	174	5.1	5,900	\$118.00	\$1.59	\$0.08	Feb. 1-Apr. 26.
1916-17.....	1200	13.1	16,885	485.45	2.42	.32	Dec. 18-Aug. 7.
1917-18.....	² 1,296	85.4	59,424	1,772.72	1.39	1.19	Jan. 1-July 31.
1918-19 ³							

¹ Includes some bulls.

² Includes only breeding cows.

³ No feeding.

The number of stock, amount of feed, length of feeding period, and cost of feed will depend largely upon the year and feed prices. In the spring of 1916 the period was comparatively short, because of rains in April and May. The years 1917 and 1918 were very dry years and the feeding period was longer. In 1918 the ranges were considerably overstocked, which accounts in part for the excessive feeding that year.

As pointed out under increasing the calf crop, the 500-head herd was fed to maintain them in thrifty condition for breeding. When the herd is kept in this condition there is, obviously, less danger of loss from starvation.

Feeding of roughage.—In case of prolonged drought the supply of range feed may near depletion or become entirely exhausted. To meet such emergencies some supply of roughage will be of advantage. Such a supply of forage is limited to (1) native forage plants that are unusable in their native state but may be prepared into feed; (2) forage crops raised under irrigation; (3) dry-land forage crops raised during wet years and stored for emergency purposes. Of these, feeding prepared from native forage plants offers the best possibility thus far.

Feeding of soapweed.—The use of soapweed as emergency feed (Pl. X, fig. 2) was first started on the Jornada Range Reserve in 1915 by making ensilage out of the tops of the plants.²¹ When fed in 1916, 1917, and 1918 this ensilage gave very satisfactory results. During the fall of 1917 machinery for cutting soapweed was developed, and

²¹ Jardine, James T., and Hurtt, L. C., Increased Cattle Production on Southwestern Ranges, U. S. Dept. of Agr., Bul. 588, 1917, p. 26.

extensive use was made of this plant as feed in the spring of 1918. Complete details for handling and feeding this plant are given in another bulletin.²²

A total of 353 tons of chopped soapweed and 47,090 pounds of cottonseed meal was fed in feeds of 15 to 20 pounds of soapweed and 1 to 1½ pounds of meal per day, to a total number of 845 head of cows from the main breeding herd between January 20 and June 11, 1918. Some of the stock were on feed the entire period, and others were fed only a part of the time. Poor cattle fed this amount of soapweed and cottonseed meal daily were maintained with very little loss, and part of the stock gained slightly.

The cost of feeding soapweed and meal was \$3.23 per head actually fed, or \$1.84 per head when the entire main herd is considered. The cost of preparing the soapweed was \$3.72 per ton,²³ and cottonseed meal, including labor in feeding, cost \$60 per ton. The average daily ration of prepared soapweed and cottonseed meal cost approximately 7 cents per day.

The slow growth of this plant and the time required to replace a stand of soapweed, once it has been cut, however, warrants its use only as an emergency ration, at least until more definite information is available to determine the actual time required for replacement.

The use of forage from irrigated farms will depend upon the availability of such forage and the cost of feeding. During 1918, 873 weaned heifer calves were fed ensilage on a farm in the Rio Grande Valley, adjacent to the reserve, at the rate of 14.3 pounds of ensilage and 0.8 pound of cottonseed meal per day for a period of approximately 85 days. The ensilage cost \$7 and the cottonseed cake \$60 per ton. This was at the rate of \$2.22 per month for a calf. A grown cow would require at least 17 to 20 pounds of ensilage and a pound of cottonseed meal per day, which would cost \$2.70 to \$3 per month for feed alone, on the basis of prevailing prices of ensilage and cottonseed meal in 1918. Under southwestern range conditions, such high prices for feed are warranted only in case of extreme emergency and for short periods.

Dry-farming forage crops have been raised under conditions of slightly better rainfall than prevails in southern New Mexico, but little or no success has been obtained where the average annual rainfall is as low as at the Jornada Range Reserve. Raising forage crops in southern New Mexico in the average year is a possibility

²² Forsling, C. L., Chopped Soapweed as Emergency Feed for Cattle on Southwestern Ranges, U. S. Dept. of Agr., Bul. 745, January, 1919.

²³ The cost of converting soapweed into feed was \$2.27 per ton in 1918, when equipment and labor were operating satisfactorily. On account of imperfection and difficulty in obtaining skilled labor there were often long delays and loss of time which resulted in an average cost of \$3.72 per ton.

only under better methods of nonirrigated farming than are now known. However, in the wettest years over most of the Southwest there is sufficient moisture to raise a fodder crop, especially on areas flooded by the run-off from nearby hills. Fodder raised in these years and cut green and stored in a silo, if in sufficient quantity, would constitute a valuable supply of reserve feed. Crops of the sorghum group were raised successfully in the vicinity of the Jornada Range Reserve in 1913 and 1914. A pit silo with a capacity of 250 tons was constructed at a cost of \$300 on the reserve in 1915 for storing soapweed. Such a silo could also be used for storing ensilage, and several of them located at strategic places on the range and filled with feed would be an excellent assurance against losses during drought.

Feeding of roughages at best is an expensive proposition, and requires care in order that costs may not become excessive. The greatest care, perhaps, may be exercised in judicious planning to begin feeding a small portion of the stock early enough to relieve the range somewhat and thus avoid the necessity of feeding a large number of stock later. A smaller number can be handled for a long period much more economically than a larger number for a short time.

Handling poor cattle.—A great deal of the success and economy in the results from measures taken to avoid losses depends upon the way the cattle in poor condition are handled. Good results can not be expected where poor cattle are left to compete with stronger individuals for feed and water. Unwarranted rounding up, rough handling, and constant moving are detrimental to cattle and should be avoided; but, as some handling is necessary in getting the animals to feed and in grouping them for feeding, it should be done slowly and carefully.

The best results have been obtained on the Jornada Range Reserve when the poor cows were segregated from the stronger stock and fed according to their requirements. In the spring of 1918 the poor cattle were divided into several different lots, varying from very poor cattle almost "on the lift" to stronger dry cows that subsisted on dry range forage alone. Each lot was carefully watched and weaker cows placed where they would receive more feed, or stronger cows removed from the feed lot, as the case might be. This was accomplished by slow, careful working of the stock when they were at watering places, thus avoiding rounding up or running them. When it was necessary to move poor stock any distance it was done by slow, careful handling with minimum ill effect. They would be moved only short distances each day and then allowed to rest and graze, or were fed. Constant riding and looking after stock made it possible, in most cases, to note the condition of poor individuals in sufficient

time to get them on feed before there was danger of their starving to death. Riding among and handling range cattle may have a slight tendency to disturb and annoy them, so that they may not do so well at first. This has even led some stockmen to the opinion that it is best to disturb them as little as possible. Experience has shown, however, that this is true to a slight extent only with the native cattle, and that the better grades which have practically replaced the native stock have now become accustomed to handling and are not injured by it, providing it is slowly and carefully done. Even timid cattle soon learn to come to feed, and if carefully handled receive the full benefit from it.

Comparison of starvation losses.—The measure of results from the steps taken to avoid losses from starvation is shown by a comparison of the losses of stock that have occurred on the Jornada Range Reserve since the problem was attacked, and losses under open range conditions in southern New Mexico for the same period. Such a comparison is made in Table 26.

TABLE 26.—*Losses of live stock from starvation on the Jornada Range Reserve and on open southern New Mexico ranges.*

Year.	Jornada Range Reserve.		Open range.	Entire State. ¹
	Main herd.	500 special herd.		
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	
1916.....	0.3	0.0	12	} 25 per cent of all stock in the State. ³
1917.....	1.0	.4	15	
1918.....	2.5	.4	35	
1919.....	² 1.0	.0	5	
Average.....	1.2	.2	16.7	

¹ Data furnished by Cattle Sanitary Board of New Mexico. Losses heavier in northern part of State because of severe winter of 1918-19.

² Herd on the reserve only part of the year, but figure applies to whole year.

³ Although this figure includes some losses from other causes, losses are mainly due to starvation.

Records for losses on the Jornada Range Reserve are made from actual observations of stock that died. Since poorest stock are handled in small pastures and around feed lots, and the entire range covered by riders many times during each year during round-ups and on other occasions, very few dead stock are missed. The records for the outside are compiled from careful estimates from observation by stockmen and others connected with the livestock industry, and are considered reliable.

The comparatively low losses on the Jornada Range Reserve in the main herd are attributed directly to the method of management to provide for needy stock during the period from January until rains occur in the summer, and to reducing the number of stock on the range in time of drought. The additional cost for feed was not

excessive. So great an expense as \$3.03 per head is not unwarranted so long as losses are kept down and the calf crop is more nearly that in average years.

There was practically no feeding in 1919, when the breeding herd was scattered over an adjoining open range where there was a reasonable amount of winter forage. The 1 per cent loss which occurred would largely have been avoided had the few poor cows been picked up and placed on feed.

The cows in the special herd were fed and given better care than other stock on the reserve, the cost of feed amounting to \$3.87 per head in 1918. Care was exercised not to overstock the range and to provide reserve range for winter and spring use. These cows were maintained in thrifty condition for breeding, and the calf crop was materially increased. Maintaining them in this condition has resulted in reducing the loss from starvation to less than one per cent in four years.

There is no doubt as to the justification of the additional care taken and feeding which has been done in the main herd on the Jornada Range Reserve. The saving in the reduction of losses alone, as compared to losses on open range, will more than pay for the feed and care, to say nothing of a slight increase in calf crop. The part which even greater feeding of stock has played in increasing the calf crop 10 to 20 calves per 100 cows and almost eliminating losses from starvation in the special herd indicates that even greatly increased feeding in the main herd would be warranted. The amount of feeding and care that will be more than paid for in decrease of loss and in increase of calf crop has not been exceeded even in the special herd, and it is doubtful whether it has even been reached.

Reserving range with an adequate water supply for use during winter and spring may be considered the basis of management, and handling stock to avoid losses from starvation with the other steps as supplemental. Without such a supply of forage the cost of feeding becomes excessive, and other measures have less value. With the range forage available supplemental feeding is practical; but without it feeding must include the use of roughage as well, and such feed at a reasonable price is extremely limited in the semidesert country.

The principal requirement of the range to be reserved for winter use is that it contain a suitable class of forage, such as grasses that cure on the range and make good winter feed, and palatable browse, with an adequate water supply. Black grama and other grama grasses are the principal grasses valuable for this purpose in the Southwest. Where other grasses are present they should be used for summer range.

REDUCTION IN LOSS FROM DISEASES AND PARASITES.

Blackleg.—In the past blackleg has been the main cause of losses from disease. In May, 1915, for example, 50 head of yearling steers died of blackleg in one herd of about 1,000 head. All yearlings were vaccinated immediately and losses stopped. Systematic vaccination of all stock between the approximate ages of 5 months and 20 months was started in the fall of 1915, and has been continued since.

The Government blackleg vaccine was used the first two years, with special care to secure proper preparation and administration. All stock of the more susceptible age²⁴ were vaccinated twice and sometimes three times a year, usually during fall branding and once or twice in the spring. The experience with the Government vaccine has been that a high per cent of immunity resulted from vaccination, but that the period of immunity was short, usually from 3 to 6 months.

The loss attributed to blackleg on the Jornada Range Reserve among calves vaccinated with the Government vaccine in 1916 and again in 1917 was approximately 1 per cent for stock 5 to 20 months of age. These results are very good as compared with the 5 per cent loss in one month in 1915, before vaccination was started. The Government vaccine requires rather frequent administration, however, and the cost of rounding up and jamming the cattle incident to vaccination two or three times a year is no small item.

Since the fall of 1917, all calves have been vaccinated with a germ-free serum developed at the experiment station of the Kansas Agricultural College. This vaccine has been administered to calves 4 to 5 months of age and up, during fall branding and during weaning time in winter. Each calf vaccinated is marked by "bushing" its tail to distinguish it from those that have not been vaccinated. Where calves are not weaned but left on the range good results have been obtained by working the stock at watering places for several days, vaccinating the calves and yearlings and turning them back on the range.

Since 1917, in so far as it has been possible to determine, no calves or yearlings treated with this vaccine have died from blackleg. A few losses attributed to blackleg occurred when the work was delayed and some calves reached the susceptible age before being vaccinated. Undoubtedly some deaths occurred also among calves that were missed. The loss from this disease has been reduced to less than 0.1 per cent of stock of susceptible age with the use of the improved vaccine.

Systematic vaccination is possible under open-range conditions, and the good results obtained from both the Government vaccine and

²⁴ Calves 5 to 20 months of age are considered more commonly susceptible to blackleg, but stock both older and younger have been known to die from the disease.

the germ-free vaccine when properly and carefully administered certainly warrant the attention of all stockmen in eliminating the losses from this disease.

Scabies.—An outbreak of scabies in the herds on the reserve in 1919 contributed materially to the poor condition of the stock that year. The disease caused stock to fall off in flesh rapidly, causing danger of loss from starvation. The infestation of stock on the Jornada Range Reserve was cleaned up in a single dipping campaign of two dippings in lime-and-sulphur dip at intervals of 11 to 14 days, under the direction of the United States Bureau of Animal Industry. A detailed description of the disease and treatment is given in *Farmers' Bulletin* 1017.²⁵

Parasites.—The two most common parasites on cattle on southwestern ranges are the louse and the spinose ear tick. They are most prevalent during winter and spring months, when stocks are in the poorest condition. While these parasites do not cause death directly, they lower the vitality of the stock by drawing nourishment from the blood of the host and detracting from quiet grazing through constant irritation, thus contributing indirectly to losses by starvation.

Both long-nosed and short-nosed ox lice are common on Southwestern ranges. These parasites spread rapidly where cattle are handled on feeding grounds. Dipping in arsenical or nicotine dip is recommended by the Bureau of Animal Industry for control of lice on range cattle. A single dipping of year-old stock in low-strength arsenical dip just before they were removed to summer range on the Jornada Range Reserve in 1917 was effective in checking the lice infestation, thus giving the stock additional advantage on the range.

As many as 110 ear ticks have been taken from the ears of one yearling heifer on the Jornada Reserve. The injury caused by these ticks in drawing blood from their host and the constant irritation contribute in no small degree toward weakening a poor animal. A mixture of two parts pine-tar and one part cottonseed oil, in doses of about one-half ounce, applied to the ears of the infected animal, as recommended by the United States Bureau of Animal Industry to check the ear tick, has been used to some extent on stock on the Jornada Range Reserve. Treated animals were rid of the pest for a sufficient period to be of value in improving their condition, but reinfestation usually occurred in from 2 to 7 weeks. The ticks live apart from their host for long periods, and stock pick them up around watering places, corrals, etc.

²⁵ Imes, Marion, *Cattle Scab and Methods of Control and Eradication*; U. S. Dept. Agri., *Farmers' Bul.* 1017, December, 1918.

More complete information will be found on both lice and ear ticks in publications by the United States Bureau of Animal Industry.²⁶

REDUCTION IN LOSS FROM POISONOUS PLANTS.

There are a number of poisonous plants on the semidesert ranges of southern New Mexico. Among these may be mentioned two suspected species of *Astragalus*, rattle-weed loco and blue woolly loco,²⁷ which occur on and in the vicinity of the Jornada Range Reserve.

Heavy losses among both cattle and horses on range adjacent to the Jornada Range Reserve were attributed to the rattle-weed during the winter and spring of both 1917 and 1918. The range was so closely grazed that there was little other forage available, and both classes of stock ate the rattle-weed freely. The same species occurs to a considerable extent on the Jornada Reserve, but other forage was always available, and no losses were experienced from it under these conditions. This leads to the assumption that cattle do not begin to eat the rattle-weed as long as there is sufficient other forage on the range.

The most effective means of avoiding losses from rattle-weed, unless eradication is practicable, appear to be to avoid grazing the range too closely and to feed susceptible stock.

OTHER CAUSES OF LOSS OF STOCK ON THE RANGE.

Some other causes which contribute to the aggregate losses on southern New Mexico ranges are predatory animals, accidents which may or may not be avoided, and grazing horses and mules on the same range with cattle.

Coyotes cause occasional loss among young calves, but such losses occur mainly when cows are too weak to protect their calves. An occasional lobo wolf or mountain lion may cause some loss. The work of the Biological Survey of the United States Department of Agriculture in eradicating these animals has been a very important factor in decreasing losses from this cause, and with continued activities of this bureau such losses should eventually become negligible.

Weak cows are sometimes lost in spring from getting stuck in bog holes. Such places should be fenced or watched to see that weak cattle are kept away and that any cows that may have become bogged down are pulled out.

Horses and mules will often stampede around watering places and run over and injure weak cattle and sometimes kill young calves. If it can be avoided, this class of stock should not be allowed among weak cows or those with young calves.

²⁶ Imes, Marion, "Cattle Lice and How to Eradicate Them," U. S. Dept. Agr., Farmers' Bul. 909, February, 1918. Also, "The Spinose Ear Tick and Methods of Treating Infested Animals," U. S. Dept. Agr., Farmers' Bul. 980, May, 1918.

²⁷ Rattle-weed loco=*Astragalus allochrous*; blue woolly loco=*Astragalus bigelovii*.

TOTAL LOSSES ON THE JORNADA RANGE RESERVE.

Losses from all causes among all classes of stock on the Jornada Range Reserve since July 1, 1915, were 1.9 per cent on a basis of the full year up to December 31, 1915, 1.5 per cent in 1916, 1.8 per cent in 1917, 3.5 per cent in 1918, and 1.5 per cent in 1919, or an average annual loss of 1.9 per cent.

Reports received from stockmen in connection with the investigations of live-stock production in the 11 far western States in 1914 showed average annual losses for New Mexico as follows: Calves up to 12 months of age, 10.6 per cent; yearlings, 5.6 per cent; stock over 2 years old, 5.8 per cent; an average of 7.2 per cent from all causes.²⁸

The estimated losses for southern New Mexico since 1914 were: 10 per cent in 1915, 12 per cent in 1916, 15 per cent in 1917, 35 per cent in 1918, and 5 per cent in 1919, or an average annual loss of 16.7 per cent for the 5-year period. The Cattle Sanitary Board of New Mexico estimates the losses for the whole State to have been 25 per cent of all the cattle in the State during the drought and severe winter of 1918-19. While these figures include some losses from other causes, they are principally due to starvation.

The results on the Jornada Range Reserve to date in reducing losses from starvation, blackleg, and other causes justify the serious consideration of stockmen. This is especially true under the existing conditions of increased cost of range, labor, equipment, and supplies, and poor credit with high rate of interest on loans to finance the business.

INCREASING GROWTH OF YOUNG STOCK.

Young stock do not make much gain in weight on southern New Mexico and similar ranges from December until the time green grass comes in the following summer. Successive weighing of steers in November and December, when they are 18 months of age, and in May or June, at 24 months of age, show little or no gain in weight during the six-months period. This stunting makes young stock slow to respond in growth when green grass comes. As a result, yearling or two-year-old steers from these ranges are not fit to go to the feeders, but find their market mainly as stockers to go to northern pastures for one or two years' maturity. As stockers for this purpose they do not bring a very high price in comparison with prices received for stock of the same age from other sections.

The stunting of young stock is even more pronounced during drought. As has already been stated, yearlings from southern New Mexico during the drought of 1916-1918 were often 100 pounds under their average weight, resulting in heavy "cut back" by

²⁸ Barnes, Will C., and Jardine, James T., Meat Situation in the U. S., Part II, U. S. Dept. Agr. Sec. Rept. 110.

buyers and lower prices for those taken. This cut-back in 1917 and 1918 varied from 10 to as high as 50 per cent of yearlings offered for sale. Prices paid for yearling steers have not advanced in New Mexico since 1916, in spite of some improvement in grade, while there was marked advance in prices paid for this class of stock elsewhere from 1916 to 1919. According to information furnished by the Cattle Sanitary Board of New Mexico, the maximum average high price has been \$40 since 1915, while the average minimum price has dropped from \$39 per head in 1916 to \$25 in 1918 and 1919. This lack of increase in price is traceable to the lack of growth in young stock in time of drought. Young heifers, too, did not make normal growth, and while fewer of these are sold, they are often set back so that they are not in fair breeding condition.

Eliminating the period of no growth, or having young stock in condition to respond quickly and make more rapid growth after feed comes, would mean a higher price for the steers to go as stockers to northern pastures, and possibly would produce a steer that would go direct to the feeder. Improvement along this line is important to obtain maximum returns from the attention and expense required to grow better-grade stock.

SELLING STEERS AND SURPLUS HEIFERS AS CALVES.

Selling steers and surplus heifers as calves in the fall would eliminate carrying them over the most expensive period of the year. The better grade of stock similar to that now being raised on the Jornada Range Reserve should find a ready market as calves among feeders in the farming States. This practice will be largely limited by two factors—lack of uniformity in age of calves in the fall and the necessity of holding over stock to consume surplus forage not needed by the breeding herd.

The breeding season on Southwestern ranges is ordinarily considered yearlong, and as a result, calves are dropped throughout the year, although mainly from March to July. Consequently, a large number of calves too young to sell in the fall must be carried through the winter and sold the following year. Restricting the breeding season to a certain period of the year would result in more uniformity in size of offspring at time of sale.

Selling most of the steers and surplus heifers as calves, however, will not leave sufficient stock on a range to consume surplus forage in good years, an essential part of range management where drought occurs. In such cases the practicability of selling calves will depend upon the grade of stock being raised. If the greatest profit from good grade stock may be obtained by marketing the product as calves it may be advisable to sell the calves raised each year and in good years when there is surplus forage purchase cheaper steers.

In either case, whether selling as calves or holding over until yearlings, there will be a number of young stock, including heifers retained to replace culls in the breeding herd, which will be carried over the dry period from November until July the next year. Maintaining the growth of such stock over this period, or at least having them in condition so that they will respond quickly when the green grass comes, should make such stock grow out better and heifers mature earlier for the breeding herd.

SUPPLEMENTAL FEEDING OF YOUNG STOCK.

Feeding the young stock a small amount of cottonseed-cake or meal to supplement the native forage and make it a better growing ration from late fall until rains occur the following spring or summer should result in eliminating the dormant period in growth of calves and yearlings at this time. At least, the young stock should be in condition to start growth sooner and make more rapid gains when green feed does come. The benefits from feeding early weaned calves a small ration of cottonseed cake during this period on the Jornada Range Reserve in 1916, 1917, and 1918 have demonstrated that it is a practicable undertaking with that class of stock. Feeding a number of two and three-year-old steers several pounds of cottonseed cake per day while on grass in 1914 and 1915 indicated that it was not practicable to try fattening steers for the market in this way; for bringing them into condition suitable for feeders it was considered a success. As better grades of stock are raised this procedure may be practiced with even greater success, and the Southwestern breeder will eventually establish a better market for his product than is now available.

FUTURE PLANS FOR THE JORNADA RANGE RESERVE.

Plans for the future on the Jornada Range Reserve include selling the best steer calves in the fall to feeders in the corn belt, if possible, and feeding all young stock retained three-fourths to 1 pound of cottonseed cake per day for 90 to 120 days in the spring to keep them growing during this period. Results to date in feeding seem to justify such practice. With the increased cost of handling and producing stock in general every opportunity for increasing the profit is worthy of consideration and trial.

In choosing the most desirable plan, the main object and one that Southwestern producers should bear in mind, however, is to produce the kind of animal for which there is greatest demand and that the best range and feeding facilities will permit.

SUMMARY.

Periodic droughts causing heavy losses, low calf crops, and interference with building up of herds are the chief set-backs to the cattle

industry in the Southwest at present, and one of the biggest problems of the industry to-day is to overcome these unfavorable conditions. Rainfall records over a long period of years and experience of stockmen during the past two or three decades indicate that droughts of 3 to 4 years' duration may occur in each cycle of 8 to 10 years.

A study made in southern New Mexico showed that on grama-grass range drought alone if prolonged beyond the second year killed 40 per cent of the best grazing plants and reduced the quantity of forage produced approximately 50 per cent. Grazing tends to increase the effect of drought to a degree varying with the time and amount of use, but when limited during the main growing season—July, August, and September—to from 30 to 50 per cent of the proper yearly rate, it has no harmful effect. The reduction in grazing at that time does not interfere with full use of the range, since the grass cures and is valuable for winter range. To restore damaged grama-grass range to its former condition of productivity will probably require several years of judicious handling.

In the case of tobosa grass or similar range there is less dying out of the forage but the amount of feed produced varies more directly with the amount of rainfall, so that the reduction in time of drought is about the same as for grama grass. Tobosa grass is not easily injured by grazing during the growing season and is of little value for grazing after it dries up, so that it is well adapted to summer grazing.

Drought has a direct influence upon the carrying capacity of the range. Data obtained thus far indicate that range with a grazing capacity of 27 acres per cow per year will only carry stock at the rate of 32 acres per head the first year of drought, 45 acres the second, 54 acres the third, and 54 the fourth.

Cattle raising, to be successful under such conditions, must be adjusted so that the number of animals will conform to the carrying capacity of the range in time of drought. In other words, there should be a reduction to 85 per cent of the original number the first year, to 60 per cent the second, and to 50 per cent the third.

Since the Southwest is primarily a breeding section, and it is difficult to dispose of breeding cows upon short notice, the breeding herd should be confined to what the range will carry in poor years or to 50 per cent of the carrying capacity during good years. The surplus forage in good years may be utilized profitably by holding over or buying young steers or heifers to be disposed of in time of drought to make all range available for the breeding cows. The age, number, and class of such stock to carry will depend upon the forage not needed for the breeding cows and the market.

Division of grama-grass and tobosa-grass types of range, when the two occur together on a range unit, and using the former in winter

and the latter in summer will serve the twofold purpose of giving the grama grass the opportunity it requires to maintain itself on the range and of securing the maximum use of the tobosa-grass range. At the same time, it reserves a supply of range for use by the stock during late winter and until rains occur in the early summer, a period when stock on the range are always poorest. Where a range is all grama grass or similar type of range, the desired result may be obtained by deferring grazing on a portion of the range during the growing season and using it late in the year, and then rotating the system to each part of the range successively.

Proper distribution of stock for full and even utilization of the range may best be secured by adequate watering facilities, proper salting of stock, and riding. Permanent watering places should not be more than 5 miles apart on the range where the carrying capacity of the range will justify it. Stock should have plenty of salt at all times, and the salt should be placed where it is desired the stock should graze. Riding after stock to keep them on the proper range assists further in good distribution.

Increased cost of production will best be offset and returns from the industry increased through improving the grade of stock, raising a larger percentage of calves, and reducing the losses from the various causes.

The grade of stock may best be improved by use of purebred bulls, culling the poorer grade cows, and replacing them with the best grade heifers obtained as a result of the use of good bulls. Slightly better bulls should be obtained every few years to continue building up the herd.

Twenty-two to thirty-three more calves per 100 cows than the present average for southwestern range conditions have been obtained over a period of four years where better care and attention were given the breeding herd. Keeping cows and bulls in good breeding condition, adequate distribution of bulls, segregation of nonbreeding stock, especially during the breeding season, and breeding no cows under 20 months or over 12 years of age, are mainly responsible for the good results. Of these, the condition of the cows and distribution of bulls are by far the more important. Having a sufficient amount of winter range, supplemented with three-fourths to one and a half pounds of cottonseed cake per day from approximately February until spring or summer rains occur, will keep cows in shape to mother their calves properly and to breed again the following summer. Early weaning of her calf gives the cow the advantage of being dry longer before dropping the next calf.

Employment of range riders to keep bulls distributed among the cows is essential to secure proper bull service when stock are in comparatively large pastures. One rider can easily keep the bulls dis-

tributed among 500 cows when range is not rough and 4 bulls per 100 cows are used. A few cows with a single bull in a small pasture also secures efficient bull service.

The heavy losses from starvation in time of drought may be avoided by adjusting the number of stock to what the range will carry. The heavy loss during the usual critical period of the year may be prevented by reserving a supply of winter range for use during that period, avoiding long distances between feed and water, and feeding a small percentage of the poorest cows.

Supplementing the range forage with a small amount of some concentrated feed, such as cottonseed cake, will usually save the weak cows that otherwise would perish.

Chopped soapweed may be fed to advantage when the forage is getting short.

Early weaning of calves and careful handling of stock, including segregation of the weakest cows, are also important points in reducing losses. The extra care and feed will pay for itself in cattle saved.

Losses from blackleg may be made almost negligible by prompt vaccination. Dipping is effective in keeping stock free of scabies and lice.

The low price received for steers from the Southwest as compared with those from other localities is due mainly to the stunting in growth when the feed on the range is dry, from early winter until rains the following summer. Feeding a small amount of cottonseed cake or some such feed should aid materially in keeping the young stock growing over this period and cause them to respond quickly to green grass when it comes.

LIST OF PUBLICATIONS RELATING TO THIS SUBJECT (ARRANGED CHRONOLOGICALLY).

Div. Agros. Bull. 16, Grazing Problems in the Southwest, by J. G. Smith. 1899.

Bur. Plant Indus. Bull. 4, Range Improvement in Arizona, by David Griffiths. 1901.

Bur. Plant Indus. Bull. 67, Range Investigations in Arizona, by David Griffiths. 1904.

Bur. Plant Indus. Bull. 117, The Reseeding of Depleted Range and Native Pastures, by David Griffiths. 1907.

N. Mex. Agr. Expt. Sta. Bull. 66, The Range Problem in New Mexico, by E. O. Wooton. 1908.

Bur. Plant Indus. Bull. 177, A Protected Stock Range in Arizona, by David Griffiths. 1910.

Ariz. Agr. Expt. Sta. Bull. 65, The Grazing Ranges of Arizona, by J. J. Thornber. 1910.

Proc. Soc. Amer. For. VII: 160-7, 1912. Range Improvement and Improved Methods of Handling Stock in National Forests, by J. T. Jardine.

N. Mex. Agr. Expt. Sta. Bull. 81, The Grasses and Grasslike Plants of New Mexico, by E. O. Wooton and P. C. Standley. pp. 176, 1912 (iss. December, 1911).

Farmers' Bulletin 578, The Making and Feeding of Silage, by T. E. Woodward et al. Revised 1920.

Farmers' Bulletin 592, Stock-Watering Places on Western Grazing Lands, by Will C. Barnes. 1914.

Journ. Agr. Res. iii:93-147. 1914 (Nov. 16). Natural Revegetation of Range Lands Based upon Growth Requirements and Life History of the Vegetation, by A. W. Sampson.

U. S. Dept. Agr. Bull. 211, Factors Affecting Range Management in New Mexico, by E. O. Wooton. 1915.

The National Wool Grower for Oct., 1915. Deferred and Rotation Grazing, by L. H. Douglas.

Bur. An. Indus. Circ. 31 (6th rev.), Blackleg: Its Nature, Cause, and Prevention, by V. A. Norgaard and J. R. Mohler. 1915.

U. S. Dept. Agr. Y. B. Sep. 678, Improvement and Management of Native Pastures of the West, by J. T. Jardine. 1916 (from 1915 Yearbook).

U. S. Dept. Agr. Bull. 367, Carrying Capacity of Grazing Ranges in Southern Arizona, by E. O. Wooton. 1916.

U. S. Dept. Agr., Sec. Rept. 110, Meat Situation in the U. S., Part II. Live Stock Production in the Eleven Far Western Range States, by Will C. Barnes and James T. Jardine. 1916.

U. S. Dept. Agr. Bull. 588, Increased Cattle Production on Southwestern Ranges, by James T. Jardine and L. C. Hurtt. 1917.

U. S. Dept. Agr. Bull. 700, Climate and Plant Growth in Certain Vegetative Associations, by Arthur W. Sampson. 1918.

N. Mex. Col. Agr. and Mech. Arts, Bull. 113, Climate in Relation to Crop Adaptation in New Mexico, by Charles E. Linney and Fabian Garcia. 1918.

Farmers' Bulletin 980, The Spinose Ear Tick and Methods of Treating Infested Animals, by Marion Imes. 1918.

Farmers' Bulletin 909, Cattle Lice and How to Eradicate Them, by Marion Imes. 1918.

Farmers' Bulletin 1017, Cattle Scab and Methods of Control and Eradication, by Marion Imes. 1918.

U. S. Dept. Agr. Farmers' Bull. 1017, Cattle Scab and Methods of Control and Eradication, by Marion Imes. 1918.

U. S. Dept. Agr. Bull. 745, Chopped Soapweed as Emergency Feed for Cattle on Southwestern Ranges, by Clarence L. Forsling. 1919.

U. S. Dept. Agr. Bull. 790, Range Management on the National Forests, by James T. Jardine and Mark Anderson. 1919.

U. S. Dept. Agr. Bull. 791, Plant Succession in Relation to Range Management, by Arthur W. Sampson. 1919.

Farmers' Bulletin 1179, Feeding Cottonseed Products to Live Stock, by E. W. Sheets and E. H. Thompson. 1920. (Some references to feeding in the Southwest.)

Farmers' Bulletin 724, Feeding Grain Sorghum to Live Stock, by G. A. Scott. Revised 1921.

Farmers' Bulletin 1167, Essentials of Animal Breeding, by George N. Rommel. 1920.

U. S. Dept. Agr. Bull. 905, Principles of Live-Stock Breeding, by Sewall Wright. 1920.

U. S. Dept. Agr. Bull. 827, The Cut-over Pine Lands of the South for Beef-cattle Production, by F. W. Farley and S. W. Greene. 1921.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
20 CENTS PER COPY



UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1032

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief



Washington, D. C.

April 25, 1922

THE BLACKHEAD FIREWORM¹ OF CRANBERRY ON THE PACIFIC COAST.

By H. K. PLANK,² *Scientific Assistant, Fruit Insect Investigations*, in cooperation with the Washington Agricultural Experiment Station. (With technical description by CARL HEINRICH, *Bureau of Entomology*.)

CONTENTS.

	Page.		Page.
Introduction.....	1	Description of stages and habits—Con.	
Importance of the blackhead fireworm.....	2	Adult.....	16
The cranberry industry on the Pacific coast.....	2	Seasonal history.....	19
Features of bog management.....	3	Natural enemies.....	20
Phenology of the cranberry on the Pacific coast.....	3	Parasites.....	20
Introduction of the blackhead fireworm into the Northwest.....	4	Predacious enemies.....	21
Distribution.....	5	Control experiments.....	22
Food plants.....	5	Miscellaneous spraying experiments.....	22
Destructiveness.....	5	Demonstration spraying experiments.....	26
Number of generations.....	6	Recommendations for control.....	34
Description of stages and habits.....	7	Reflowing.....	34
Egg.....	7	Spraying.....	34
Larva.....	9	Summary and conclusions.....	37
Pupa.....	14	Systematic description of <i>Rhopobota naevana</i> Hübner.....	42
		Explanation of plates.....	45

INTRODUCTION.

Numerous complaints from Washington cranberry growers, received by the Bureau of Entomology and the State College of Washington, led the two institutions to make a cooperative investigation of cranberry pests in the Pacific Northwest in 1918 and 1919. In this joint undertaking the writer represented the Bureau of Entomology.

¹ *Rhopobota naevana* Hübner; order Lepidoptera, family Olethreutidae. Determined by Carl Heinrich, of the Bureau of Entomology.

² Appointed Collaborator, Tropical and Subtropical Fruit Insect Investigations, July 1, 1920.

mology and, successively. A. Spuler, Miss Orilla Miner, and Miss Flora A. Friese the State College of Washington.

IMPORTANCE OF THE BLACKHEAD FIREWORM.

The blackhead fireworm proved to be the most important cranberry pest of western bogs, and at the time the ravages of this insect were first observed by the writer it was causing an estimated loss of approximately 40 per cent of the combined crops of Washington and Oregon. In 1918 this loss was reduced to approximately 15 per cent and in 1919 to approximately 5 per cent, principally as a result of a better knowledge of the life history and habits of the insect and more general adoption of effective methods of control.

This bulletin reports the results of an investigation of the life history and habits of the blackhead fireworm in the States of Washington and Oregon which was conducted during the years 1918 and 1919 from laboratory headquarters at Seaview, Wash. During this period various methods of control were studied and thoroughly tested under actual bog conditions.

THE CRANBERRY INDUSTRY ON THE PACIFIC COAST.

The town of Seaview, Wash., is located practically in the center of the cranberry-growing district on the Pacific coast. In the State of Washington this district comprises most of the peninsula of Pacific County, in the southwestern corner of the State, directly north of the mouth of the Columbia River. Here the industry was started on a commercial scale in the early eighties by a French gardener named Chebot, who set out about 35 acres to the McFarlin, Native Jersey, Early Black, and Cape Cod Beauty varieties. Cuttings of most of these varieties were brought in from Wisconsin, New Jersey, and Massachusetts bogs. Some cuttings, especially of the McFarlin variety, were doubtless brought in from Marshfield, Oreg., where a Mr. McFarlin had started a bog 10 years previously with his own selection of vines from the East, which bear his name. Extensive planting, however, did not take place until 1912, from which time up to 1915 large areas in southwestern Washington were drained, cleared, and made available for cranberry culture.

Approximately 700 acres of cranberries are now in bearing in southwestern Washington, with about 1,500 acres of peat land still available for cranberry culture. In Oregon and the remainder of Washington there is possibly a total of 1,500 additional acres of cranberry land, about 300 acres of which in Oregon (in Clatsop and Coos Counties) are now in bearing. Practically all the bogs of the Pacific coast are sphagnum peat of various ages and thicknesses,

found generally in swales between shore-sand ridges of slight elevation.

FEATURES OF BOG MANAGEMENT.

Although considerable water sometimes collects on the Pacific coast bogs, especially during winter, as a result of the heavy rains from September or October to April, flooding as a distinct part of cranberry bog management is rarely practiced in that section of the country. Few bogs on the Pacific coast have a good supply of water suitable for flooding purposes, and the mild winter climate in the principal cranberry-growing region seems to obviate the necessity of protecting the vines from winter injury. Principally is this true in southwestern Washington. As a consequence many terminal buds, especially on the warmer bogs, start to unfold shortly after the vines reach maturity in September and October and a certain amount of growth usually takes place during the warmer periods of the winter. It rarely happens, however, that any material damage is done by frost.

Covering the bog with water, usually from about November 15 to March 1, is practiced only to a limited extent in Oregon, but where this procedure is followed good results are usually secured. In the southern sections of the State it is almost necessary to cover the bogs with water during this period in order to keep the terminal buds from pushing forth during the warmer periods of the winter and meeting probable damage from frost during the late winter and spring.

The application of sand once every few years, as practiced on many eastern cranberry bogs, is not practiced on the coast, but probably could be employed with benefit. Inasmuch as the majority of the bogs are located between sand ridges, an abundant supply of good sand is readily available should its use become desirable.

PHENOLOGY OF THE CRANBERRY ON THE PACIFIC COAST.

The growth of the cranberry vine on the Pacific coast bogs is exceedingly variable, as will be borne out by the data presented in Table 1. This is probably because these bogs are for the most part managed as dry bogs. The relatively variable weather in that section of the country is also doubtless reflected in the early growth, blooming, and fruiting of the cranberry. It is for these reasons chiefly that no exact dates can be given for the various stages in the phenology of the cranberry in that region.

An attempt has been made, however, after a long series of frequent observations, to determine as closely as possible the approximate dates when these stages occur in their greatest abundance. These dates are presented, therefore, in Table 1 for the earliest growing varieties, such as Early Black and McFarlin, and for the latest-growing varieties, such as Howe. There seems to be considerable variation in the growth of the varieties belonging to these two classes, the height of each stage in the growth of the latest varieties generally coming a month after that of the earliest varieties.

TABLE 1.—*Phenology of the cranberry on unfloated bogs on the Pacific coast, based on observations at Seaview, Wash., 1918 and 1919.*

Stage of development.	Approximate date of occurrence of the height of each stage on—	
	The earliest varieties.	The latest varieties.
Buds breaking and new growth beginning to push forth.....	Apr. 6	May 7
New upright growth $\frac{1}{2}$ inch to $\frac{3}{4}$ inch long.....	Apr. 10	May 14
Blossoms in "hook stage".....	May 12	June 14
Vines in full bloom.....	June 9	June 30
Blossoms falling and berries setting.....	June 30	July 30

Such local influencing conditions as depth of vines, depth of the underlying peat, or protection from the strong northwest wind which commonly blows during much of the early growing season will, of course, cause wider local variations than those here given. The limits of each phenological stage are even more variable than the height, it being not uncommon, for instance, to find blossoms on some vines as early as May 12 and on others, many not yet fully opened, by July 15. An early spring, too, would have the effect of somewhat advancing the dates given in this table and a late one would probably delay the early stages a little, but the later stages, such as blooming and setting of berries, would probably be delayed to a less extent.

INTRODUCTION OF THE BLACKHEAD FIREWORM INTO THE NORTHWEST.

Although the blackhead fireworm is found on the wild cranberry³ as far as 2 miles from any cultivated vines, the severest infestations in Washington and Oregon are on bogs planted originally with vines from Wisconsin, New Jersey, and Massachusetts. A study of the history of the cranberry industry on the Pacific coast and of the

³ Specimens growing wild in southwestern Washington were submitted to Dr. F. L. Pickett, of the Washington Agricultural Experiment Station and were determined by him as the common western cranberry, *Oxycoccus (oxycoccus) intermedius*, with the following note: "This is a little coarser than the small cranberry of the East, and bears slightly larger berries."

origin of the cuttings used furnishes convincing evidence that large numbers of the eggs of this pest were brought into this region on the leaves of cuttings from bogs in these three States. These cuttings, principally from Massachusetts bogs, were used extensively in planting a large number of bogs set out in Washington and Oregon between 1912 and 1915, which was about the time the blackhead fireworm became a pest of considerable importance in the regions from which these cuttings were imported.

After the newly planted bogs had made sufficient growth, it was the practice to mow them and use the cuttings thus obtained to plant other areas, as these cuttings could, of course, be obtained at less cost and in better condition than those from the East. So, helped in this way, the blackhead fireworm spread over practically the entire region. Once established on a bog it was a matter of only a few seasons until this pest had overrun nearly every part of it and caused considerable damage almost before the owner was aware of its presence.

DISTRIBUTION.

The blackhead fireworm is found on nearly every cranberry bog on the Pacific coast. It has long been a pest of the cranberry in New Jersey, Massachusetts, and Wisconsin, where it now causes as much damage as any other cranberry pest and often more. According to Fernald,⁴ it has also been found on the cranberry in New York and California.

FOOD PLANTS.

Numerous small larvæ resembling very closely in appearance those of *Rhopobota naevana* were found feeding on some common bog plants, such as "buck brush"⁵ and "sweet gale."⁶ None of these proved to be the blackhead fireworm; and, so far as known on the Pacific coast, *Rhopobota naevana* feeds only on the cranberry, both native⁷ and cultivated.⁸

DESTRUCTIVENESS.

The injury to the cranberry by the blackhead fireworm is caused by the feeding of the larvæ, or worms, on the buds, foliage, blossoms, and fruit throughout the growing season. It is very characteristic and quite unmistakable; there is no other pest of the cranberry on the Pacific coast the work of which is similar in all respects

⁴ Fernald, C. H. A Synonymical Catalogue of the Described Tortricidae of North America North of Mexico. In Trans. Amer. Ent. Soc., v. 10, p. 48. 1882.

⁵ Specimens of this plant were identified as *Spiraea douglasii* by Dr. F. L. Pickett, of the Washington Agricultural Experiment Station.

⁶ Also identified by Dr. Pickett as *Myrica gale*. "It belongs to the bayberry group."

⁷ *Oxycoccus (oxycoccus) intermedius*, the common western cranberry.

⁸ *Oxycoccus macrocarpus*, the common cultivated cranberry.

to that of the blackhead fireworm, nor has the cranberry there any other pest which annually destroys so much as this one.

The young larvæ start to feed on the newly growing tips shortly after they hatch, in the months of April and May, and continue their work throughout the growing season, attacking in greater or less severity the buds, blossoms, and later the berries, injuring the berries by boring into them and causing them to shrivel and dry and often to fall from the vines. The most noticeable feature of the attack of the fireworm during the middle or latter part of the summer is the burnt appearance of the vines which results from the work of this insect, suggesting the name fireworm. Since the terminals are most affected, few if any fruit buds are set when the vines are badly infested, and as a result nearly all the crops of the current season and of the following year are destroyed by the feeding of the larvæ during a single season. The vines, while never completely killed, are very much stunted and by the end of the summer are left stripped of the majority of the leaves. They are often brittle, and in the case of long-standing infestation are short and scrubby with numerous short and crooked branches as a result of being prevented from making a natural terminal growth. From this condition they do not usually return to their normal productivity until good control work has been in force for several years.

NUMBER OF GENERATIONS.

By rearing the insect from the winter egg stage in an outdoor shelter it was found that it passes through two generations and sometimes a partial third. For example, the hatching of the winter eggs starts the first generation, and the resulting larvæ which change into pupæ and moths also belong to the first generation.

The eggs that these moths lay start the second generation. Contrary to the behavior of this pest in the East, only about four-fifths of these eggs hatched to form a second generation the same season in which they were deposited. The remaining one-fifth did not hatch until the following spring.

All the eggs deposited by the moths resulting from the second set of individuals are known as the eggs of the third generation. So far as is known, in eastern cranberry regions the eggs of this generation do not hatch until the following spring. On the Pacific coast, however, it was found that about one-third of the eggs of this generation hatched late in the summer, forming a third generation of larvæ. Because of adverse weather conditions toward the latter part of the season, none of these larvæ developed into pupæ and moths. This generation is therefore called a partial or incomplete generation.

DESCRIPTION OF STAGES AND HABITS.

THE EGG.

The egg of the blackhead fireworm is smooth, slightly elliptical, with the center partially raised and rounded. It measures approximately 0.65 millimeter wide, or about the size of the head of a very small pin. When first laid it has a slight opalescent sheen and a light lemon-yellow color which changes to a deeper yellow in about two weeks. The hatched egg is more inconspicuous, being transparent and appearing much like a small drop of albumin which has dried on the leaf. (Fig. 1.)

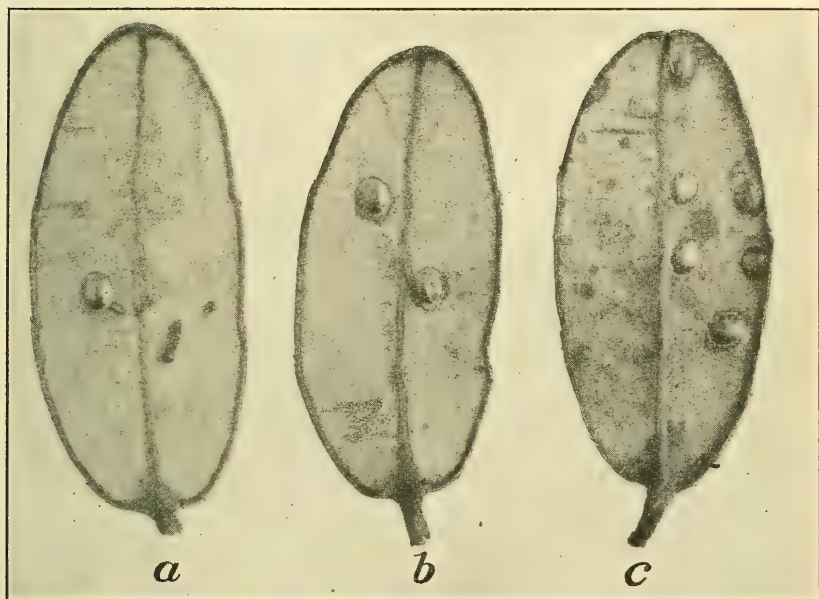


FIG. 1.—Eggs of the blackhead fireworm moth on the undersides of the cranberry leaves, enlarged 7.5 times: *a*, Winter eggs; *b*, eggs in the “black-spot” or first stage of development; *c*, hatched eggs.

HIBERNATION.

The eggs are laid by the parent moth singly or in groups on the underside of the cranberry leaves; rarely, a few eggs will be found deposited on the upper surface of the leaves. On the badly infested bogs as many as 10 or 12 eggs may be found on the underside of a single leaf. The majority of the wintering eggs are usually deposited on the leaves on the lower portions of the vines, the short, low up-rights near the ground generally containing the greatest number of eggs. During picking season and the following winter, many of these leaves are dislodged from the vines, and it is not an uncommon thing to find them on the bog floor bearing numerous eggs. An infestation may easily be distributed from one part of a bog to

another by these leaves drifting from place to place over the bog in and on the water which sometimes collects during the winter time. Instances were noted in which numerous egg-bearing leaves had been washed into a corner of a bog, where they almost covered the vines. These eggs, being the first affected by rising temperatures, were the first to hatch in the spring, and the young larvæ had almost completely destroyed the surrounding uprights before eggs elsewhere in the bog had hatched.

INCUBATION AND HATCHING.

The first signs of incubation are noted as the black head and thoracic shield of the developing larva begin to show through the chorion or eggshell. As development progresses the young larva may be seen to move within the egg and finally, as it grows in vigor, to rupture the egg wall at a point over its mandibles and gradually escape by means of a wriggling sidewise motion through this slitlike opening, which is near the top of the upper surface of the egg. (Fig. 1, *b*, *c*.) It usually takes from about 3 to 5 minutes for the larva to free itself entirely from the eggshell.

FACTORS INFLUENCING HATCHING AND DEVELOPMENT.

(*a*) *Temperature*.—Temperature has the greatest influence on the fireworm eggs as well as on the other stages. This varies more than is generally supposed among different bogs, depending upon location.

(*b*) *Depth of vines*.—Another very important factor which tends to retard or hasten development of fireworm eggs is the depth of the vines in which they are deposited. A bog with thin vines will warm up more readily in the spring and maintain a higher temperature generally throughout the season than a bog with rather thick vines. Observations show, for instance, that on bogs with thin vines, hatching generally starts during the first warm days of spring (sometimes late in March or in early or mid-April), reaches its maximum early (say towards the latter part of April), and produces moths in maximum numbers in the middle or late part of June. On a thickly vined bog, in the same locality, however, and under similar conditions of temperature and moisture, hatching, while it may start about the same time as it does on the thinly vined bog, will be only desultory until the vines have warmed up considerably. Hatching in maximum numbers may not take place then until the middle or latter part of May. This in the absence of a winter flooding distributes hatching, on bogs with a medium or heavy growth of vines, over a considerable period.

(*c*) *Drainage*.—During the winter or rainy season more or less water usually accumulates on the majority of the cranberry bogs

on the Pacific coast. On those which are not quickly and easily drained this winter water remaining on the bog late in the spring causes the vines and the fireworm eggs to be rather slow in developing, with a consequent grouping of the hatching and development of the first generation of larvæ.

THE LARVA.

The newly-hatched larva of the blackhead fireworm (fig. 2, *a*) is about 0.1 mm., or a little over one-thirty-second of an inch in length; at first it has a pale yellow color which turns to a darker yellow with age, and has a relatively large dark brown or black head, accentuated by the thoracic shield, the first segment back of the head, which is nearly as dark as the head; hence the name "blackhead."

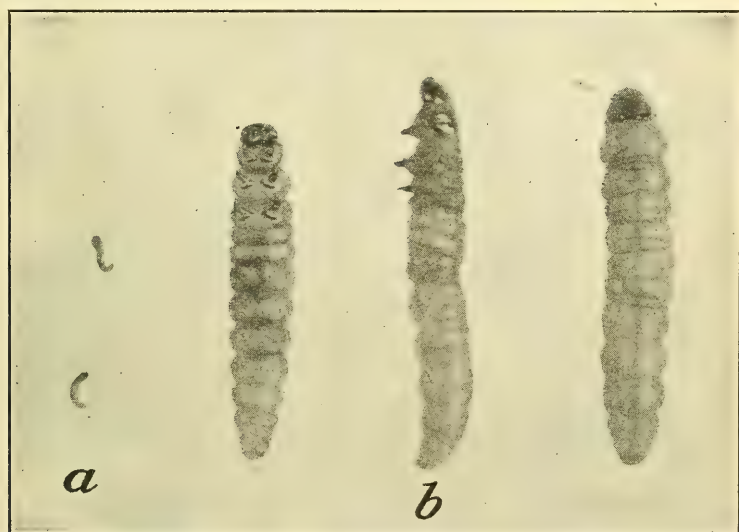


FIG. 2.—The blackhead fireworm: Views of the larva, enlarged 7.5 times: *a*, Newly hatched larvæ; *b*, dorsal, lateral, and ventral views of full-grown larvæ.

When fully grown (fig. 2, *b*) the larvæ measure about 6.5 mm., or about one-fourth inch in length, and are dark greenish yellow with a coat of darker olive green above. The head and thoracic shield are black. The larvæ are very active from the time they are about one-fifth to one-fourth grown and vigorously wriggle from their galleries when disturbed, falling to the ground and quickly concealing themselves among the trash and leaves beneath the vines by a characteristic sidewise and backward movement of the body. They are provided with three pairs of thoracic legs, four pairs of abdominal legs, and one pair of anal legs. Depending upon the weather and the time of the season, the blackhead fireworm spends from 10 to about 75 days in the larva state.

FEEDING HABITS.

A newly hatched larva begins feeding shortly after it leaves the egg, but may wander about for from 15 minutes to half an hour before taking any food. It usually starts feeding on the underside of the leaves, generally near the eggshell from which it has just emerged. At first it bites into the epidermis of the leaf, and, mixing the nibblings with the thread of silk which it spins continuously from several points beneath its lower lip, soon covers itself with a

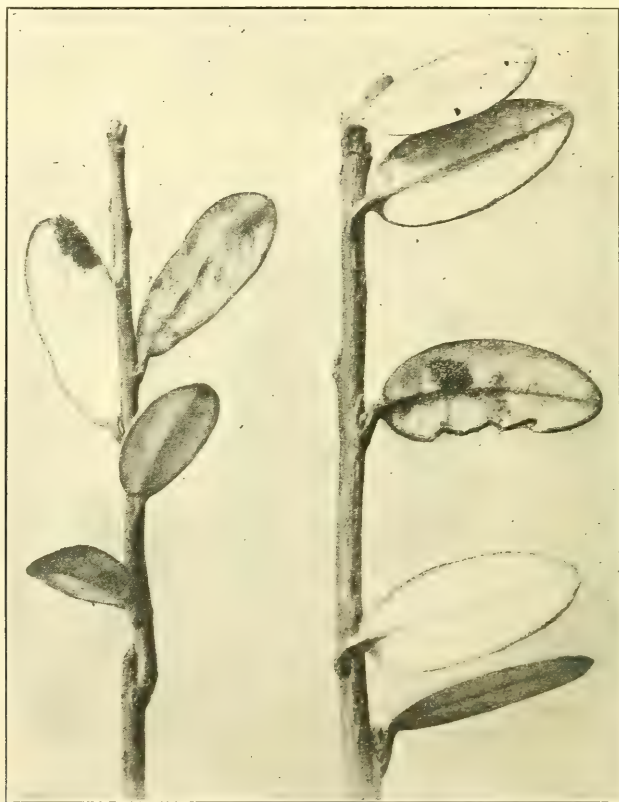


FIG. 3.—The blackhead fireworm: Characteristic work of the newly hatched larvæ on the underside of cranberry leaves.

greenish brown material which has the appearance of fine sawdust. For a time it continues to chew into the leaf, feeding principally between the upper and lower surfaces, acting in many respects like a leaf-miner. (See fig. 3.) This is particularly characteristic of the early-hatched larvæ of the first generation. The larvæ of this generation which hatch later, and usually those of later generations hatched in warmer weather after the new growth is well out, proceed almost directly to the tip, spending very little time as leaf-miners.

Depending upon the prevailing temperature and the condition of the weather at this time, the young larva in a somewhat dormant condition spends two weeks, more or less, in its burrow, feeding only when the weather is warm and favorable. If the weather is warm it will be quite active and may stay in its burrow only two or three days. On badly infested bogs it is a common thing to find the underside of the lower leaves on the vines badly chewed and full of burrows. The majority of instances of this type of injury are doubtless caused by the larva hatching early in the spring before the bogs have become sufficiently warm to permit active feeding, and also by those hatching late in the fall, as is often the case on account of the bogs being exposed to the weather the year round.

At the approach of warm weather, or after the young larva has grown larger and stronger, it leaves its burrow and proceeds toward the tip of the upright. Here, if the weather should turn cool, it starts to feed in the whorl of leaves about the terminal fruit bud and incloses itself in a loosely constructed web of frass and silk, either between two terminal leaves or between the bud and the adjoining leaf, where it awaits more favorable conditions which may cause the terminal bud to break and grow. As these conditions become intensified the larva proceeds to web up the unfolding leaves as it feeds on and skeletonizes them from within. From about the latter part of May or the beginning of June this injury is noticeable to the casual observer, many of the short, new uprights assuming a withered and bent-over appearance at the tip, similar to those shown in the accompanying illustration (fig. 4).

As the weather becomes warmer and the vine growth increases the fireworms, the majority of which at this time (about early June) may be nearly one-half to three-fourths of an inch long, feed rapidly on the leaves in their web galleries, gradually extending them or moving to an adjacent tip or upright as new food is needed. The vines gradually assume the characteristic dried, light yellow-brown appearance, and as feeding continues the bog begins to look as though a fire had swept over it, scorching the tips of the vines, which by midsummer are dry, reddish brown, and often nearly leafless; whence the name "fireworm."

On a vigorously growing bog the late-hatched larvæ of the first generation often feed upon the unfolding blossoms and newly formed berries, sometimes causing them to drop from the vines. In their feeding the young larvæ frequently burrow into the blossoms at a point near the base of the petals and feed on the floral organs within, or they may bore into the ovary directly from the outside. This feeding is first noticed about the time when the blossoms are in the "hook stage" or about the beginning of June on the early bogs. At this time a few very small larvæ usually may be seen eat-

ing into the blossoms or berries, as described above; later on, both large and small larvæ may attack the berries, eating into them where the berries touch one another or the leaves or an adjoining upright. (See fig. 5.)

The second generation of worms makes its appearance in considerable numbers the latter part of July. These larvæ not only feed upon the foliage, like those of the first generation, but they also web it up more, feed longer, and move from place to place much oftener than do the larvæ of the first generation. Especially on bogs



FIG. 4.—The blackhead fireworm. Early work of the larvæ in the tips: *a*, Entire new tip destroyed; *b*, showing how the tip leaves are webbed together; *c*, an uninjured upright.

making little new growth they may extend their feeding to the old foliage, including many of the old uprights in their webs. In addition, many of them may also feed extensively throughout the remainder of the season on berries of all sizes. It does not seem to make much difference whether the berries are webbed up or not; in fact, the majority of the berries attacked are not webbed up at all. (See fig. 5.) The injury done by the second generation of larvæ is, therefore, very striking. The third generation of worms is not very distinct from the second and not quite so numerous; but occurring

later in the season, when the vines are maturing, these larvæ feed principally on the berries, and therefore do more immediate damage to the crop if any remains on the vines.

The result of the work on all three generations is not only the destruction of the current season's crop or its material reduction but also the loss of a considerable proportion of the crop the following year, the setting of fruit buds being largely prevented by the attack of the larvæ on the terminals. It will thus be seen that the fireworm in one season can very materially reduce the cranberry crop of two seasons.



FIG. 5.—The blackhead fireworm: Injury of the larvæ to the berries. The large berry on the upright is uninjured.

PLACE OF PUPATION.

After the larvæ have reached their full growth they usually leave the webbed uprights and descend to the trash and leaves beneath the vines, where they inclose themselves between several old leaves in more or less loosely constructed cocoons, typical specimens of which are shown in figure 6. Sometimes, however, especially in the case of the larvæ of the first generation, some may spin themselves up within a thin cocoon in the tips of the uprights, as shown in figure 7. Very

often some larvæ, after feeding in a cluster of berries, will spin their cocoons and also pupate on the inside of one of them, or they may fasten their cocoons between the berries, mixing their silk with frass and any skeletonized leaves available. This is commonly true of the larvæ of the second generation. It is not very unusual, therefore, to find some berries with the empty pupa cases protruding from a hole in the side. The great majority of the larvæ of all generations, however, descend to the ground to pupate.

THE COCOON.

As previously referred to, the cocoon of the blackhead fireworm is composed of strands of silk which the larva fastens to any surrounding objects, as frass, leaves, or berries, and more or less loosely draws



FIG. 6.—The blackhead fireworm: Typical cocoons formed out of dead cranberry leaves beneath the vines. The ones in the top row have been opened to show the interior; those in the lower row show the empty pupa cases protruding. All slightly enlarged.

about itself preparatory to pupation. The interior of the cocoon is shown in figures 6, 7, and 8. It is in cocoons similar to these that the larvæ pass through a resting period followed by a final molting of the larval skin. This resting and molting, during which the pupa or chrysalis is formed, is called pupation.

THE PUPA.

The pupa or chrysalis of the fireworm is about 5.5 mm. or a little less than one-fourth inch long by 1.5 mm. or about one-sixteenth inch wide, and of a light amber yellow color immediately after casting the larval skin. This color soon changes to a deeper amber brown, and in pupæ about to change to adults the color is a very deep amber approaching almost black. The pupæ are not usually encountered without a rather close examination of the leaves and trash beneath

the vines in which, as already mentioned, most of the individuals of all generations pupate. (See fig. 8.)

The pupæ wriggle considerably when first picked up, moving the end of the abdomen in a circular motion, but they have no power of locomotion such as the larvæ have. Just before the moth is ready to emerge, and in order that it may do so without hindrance, the pupa,



FIG. 7.—The blackhead fireworm: Pupa in cocoon spun in a tip of a cranberry upright. Enlarged 6 times.

by means of this wriggling motion and with the aid of a number of small backwardly directed spines arranged in double rows around the back of each segment of the abdomen, forces itself out through the end of its loosely spun cocoon until the thorax and the tips of the wing pads are free of the edge of the cocoon. (See last specimen at right in lower row of fig. 6.)

The duration of the pupa stage varies from 10 to about 65 days, depending upon the weather and the time of the season.

THE ADULT.

The adults, or moths, of the blackhead fireworm are conspicuous because of their habits of flight; when disturbed they often rise in very large numbers. Upon close examination they are found to be small in size, measuring in length from the tip of the head to the tip of the wing on the average about 6 or 7 mm., a little over one-fourth of an inch, or about the same length as the mature larvæ. With the wings spread they measure about 10 mm. across, or a little over three-eighths of an inch.

The moths (fig. 9) differ somewhat in color, seeming to vary especially according to age. The first pair of wings of freshly emerged



FIG. 8.—The blackhead fireworm: View of pupa and interior of cocoon. Enlarged about 7.5 times.

and unrubbed specimens have a ground color above of deep silver gray, with irregular markings of brown, which often give them a golden-brown sheen. Characteristic markings of a single row of short alternating brown and silver-gray bars running diagonally to the front margin are found on the first or upper pair of wings. The second or lower pair of wings of the female are without characteristic markings; those of the male have an irregular dark spot on the underside near the front margin. The second or lower pair of wings of both male and female have a fringe of long, bristlelike scales extending from near the tip along the back margin to the body. The abdomen is medium and slender, depending on the sex, female specimens having a somewhat broader and shorter abdomen than the males. The abdomen and the legs are covered with dark silver-gray scales, which

often have a light golden-brown sheen. The antennæ are about one-half the length of the body and more or less bristlelike.

The adults live from 3 to 33 days after they emerge, and during this time eat little or nothing, except, perhaps, a little nectar from the blossoms, or water in the form of dew or rain.

HABITS OF FLIGHT.

After the moth emerges from the pupal case it rests for a short time, during which the wings are spread and dried. It then starts to fly and moves rather swiftly in a short, jerky, darting motion, making usually only short flights from place to place over the vines. Particularly on heavily infested bogs the moths are very conspicuous for their habits of flight. They will often be seen to rise in large numbers when disturbed, as by spraying or by a person walking through the vines on a warm afternoon, suggesting to some the appearance of a cloud.

PERIODS OF ACTIVITY.

A few moths may generally be seen flying from tip to tip almost every hour of the day from the time of their first appearance in June until late in September and October, but the time of day they are most active is from about 3 o'clock in the afternoon until after dusk. During this period, especially if the weather is warm, they may be seen to rise in the air for a few feet, making their characteristic short, jerky flights.

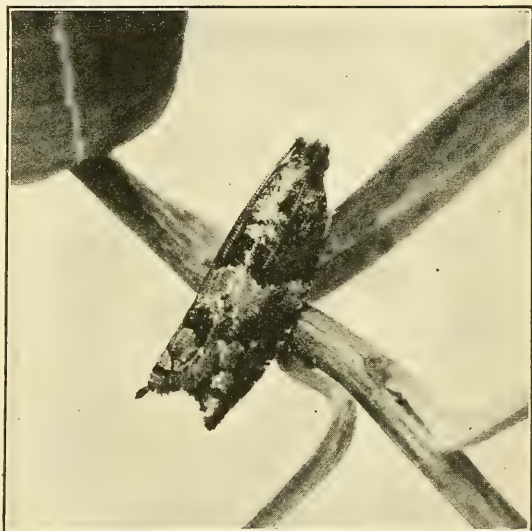


FIG. 9.—The adult or moth at rest on a cranberry upright. Enlarged about 6 times.

MIGRATION.

It is in the moth stage principally that the blackhead fireworm spreads itself over the bog or invades an adjoining one. The moth, however, flying only short distances, would not naturally migrate more than several yards from its original region of activity; but, helped by the wind, it is possible for it to be carried as far as several

hundred feet in one flight, and it is thus that bogs neighboring badly infested ones, especially to the leeward, may become badly infested in a few seasons.

Other ways in which the fireworm is disseminated over a bog have been mentioned, namely, in the egg state, on leaves floating over the bog in the winter water (p. 7-8), and also on cuttings (p. 4-5).

PROPORTION OF SEXES.

In 1918, of 158 moths of the first generation emerging in the insectary, 81, or 51 per cent, were males, and 77, or 49 per cent, were females; of 59 moths of the second generation, 24, or 41 per cent, were males, and 35, or 59 per cent, were females. In 1919, of 101 moths of the first generation emerging in the insectary 53, or about 52 per cent, were males, and 48, or about 48 per cent, were females; of 52 moths of the second generation 24, or 46 per cent, were males, and 28, or 54 per cent, were females. This shows a slight predominance of males over females in the first generation and the opposite in the second generation.

COPULATION.

Copulation usually occurs shortly after emergence. Of those pairs observed in the rearing shelter, one was found copulating the same day it emerged, two the day after emergence, and one pair did not copulate until 7 days after emergence. The same pair was never seen to copulate more than once.

The period of copulation varies in length, the minimum period observed being 1 hour and 26 minutes and the maximum 26 hours and 55 minutes. The male of one pair observed was noted dead and still attached to the female 3 days after copulation was first observed.

OVIPOSITION.

Egg-laying commences shortly after copulation, usually within a few days. During oviposition the female rather quickly pushes the egg out through the tip of the abdomen, which she holds very close to the underside of the leaf. Here the egg, a soft, plastic drop, settles over the surface and soon assumes its ordinary flat, oval shape. The outermost covering, which is rather moist when the egg is first laid, dries and cements the egg to the leaf and gives it its appearance of being glued on. (See fig. 1, *a*.)

TIME OF DAY WHEN OVIPOSITION OCCURS.

Eggs may be laid at almost any hour of the day and evening when the weather is warm and fair. However, in order to determine the time of day when the moths were depositing eggs in largest numbers,

32 males and 42 females of the first generation were collected from a cranberry bog on July 15, 1918, and immediately confined as follows in three battery jars 9 inches high by 5 inches wide: Jar No. 1 contained 12 males and 12 females; jar No. 2, 10 males and 12 females; jar No. 3, 10 males and 18 females. Each jar was provided with a few inches of slightly moist sand on the bottom, an abundance of clean cranberry uprights, and a sponge moistened with a weak solution of sugar and water for food and moisture,

Every 3 hours from 2 a. m. to 9 p. m. daily until July 20 the uprights in each jar were replaced with fresh ones and the eggs on them and on the side of the jar counted and recorded. The sponge was also moistened daily.

The number of eggs found deposited at each examination is summarized in Table 2. As will be noted therein, eggs were laid during every period between examinations, but the largest number of eggs was deposited between 3 p. m. and 9 p. m., 663, or 39.6 per cent of the total, being deposited between 3 and 6 p. m., and 650, or 38.8 per cent, between 6 and 9 p. m. The smallest numbers were deposited in the 12-hour period between 9 p. m. and 9 a. m. It will be noted further that the time of day during which eggs were deposited in largest numbers is also the period of greatest activity on the bog.

TABLE 2.—*Number of eggs of blackhead fireworm moth deposited every 3 hours from 6 a. m. to 9 p. m. by moths of the first generation confined in battery jars; Seaview, Wash., July 15 to 20, 1918.*

Period of deposition.	Number of eggs deposited.	Per cent of total deposited.	Period of deposition.	Number of eggs deposited.	Per cent of total deposited.
9 p. m. to 6 a. m.	78	4.6	3 p. m. to 6 p. m.	663	39.6
6 a. m. to 9 a. m.	8	.5	6 p. m. to 9 p. m.	650	38.8
9 a. m. to 12 noon.....	67	4.0			
12 noon to 3 p. m.	209	12.5	Total.....	1,675	100.0

The number of eggs found deposited at each examination is shown in graphic form in figure 10, together with a curve showing the hourly temperature during the period of the experiment. Attention is here drawn to the influence of the temperature on egg-laying. It will be noted that the largest number was deposited between 3 and 6 p. m. on July 16, a few hours after the highest temperature, namely, 75° F., was recorded.

SEASONAL HISTORY.

It was noted that larvæ of the first generation appeared in greatest abundance on the bogs about the latter part of May, the pupæ toward the middle of June, and the moths about the first or second week in July.

Because of the overlapping of the generations, one can scarcely do more than speculate as to the date of occurrence of the stages of the second and third generations on the bogs; and the latest dates of the occurrence, particularly of the moths of the first generation and all the stages of the second and third generations, could only be obtained, therefore, by rearing methods.

NATURAL ENEMIES.

PARASITES.

INSECTS.

Although numerous very small wasplike insects (members of the order Hymenoptera) can be seen flying over the tops of the vines on

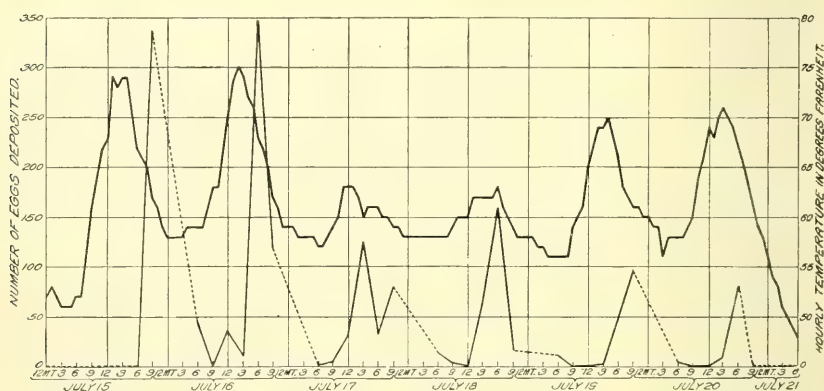


FIG. 10.—Egg deposition by blackhead fireworm moths of the first generation. Records every three hours from July 15 to 20; Seaview, Wash., 1918.

badly infested bogs on warm, clear days, none of these could be reared from collections of the eggs and larvæ of *Rhopobota naevana* from various bogs. Circumstances indicate very strongly, however, that the blackhead fireworm on the Pacific coast is parasitized, to a certain extent at least, although not as much as on some dry cranberry bogs in the East.

FUNGUS DISEASE OF THE PUPÆ.

From about the beginning or middle of August it is very common to find, especially on the older and more badly infested cranberry bogs, areas of 3 to 5 inches or more in diameter of old leaves beneath the vines which have the appearance of being smeared with a floury-white substance. Closer examination of these areas will show that this whitish appearance is due to the fruiting growth of a parasitic fungus,⁹ which attacks and kills the pupæ concealed in their cocoons in these old leaves. This fungus is shown growing from the

⁹ Determined by Dr. A. T. Speare, of the Bureau of Entomology, as a species of *Spicaria*.

cocoon in the lower row of specimens in figure 11. The specimens in the top row have been dissected from the loosely constructed cocoons and show the fungous disease growing on the pupæ.

While this disease certainly causes the death of a large number of pupæ on bogs where it is prevalent, not too much reliance should be placed on it in the control of the fireworm, since the greatest part of the damage by the fireworm is done to the vines before the time when the fungous disease is growing rapidly. The weather also may or may not be favorable to its rapid growth, and hence its killing power and spread are likely to vary considerably from one season to another.



FIG. 11.—Fungous disease, a species of *Spicaria*, growing from the blackhead fireworm pupæ in their cocoons. Slightly enlarged.

PREDACIOUS ENEMIES.

SPIDERS.

On the cranberry bogs of the Pacific coast spiders of various kinds are found in very large numbers and doubtless devour many fireworm larvæ and moths.

INSECTS.

A large number of "ladybugs" are also seen on cranberry bogs, and their presence there sometimes causes alarm to a grower who is not familiar with their habits. One species, the California red ladybird beetle,¹⁰ is very common, and both larvæ and beetles can be seen actively walking over the tips of the cranberry uprights any

¹⁰ Specimens determined by Mr. E. A. Schwarz, of the Bureau of Entomology, as *Coccinella californica* Mann.

time throughout the summer. The ladybird beetles, with few exceptions, are beneficial insects; the adults of this species have been observed to feed readily on the larvæ of the blackhead fireworm in captivity, and in the field doubtless consume large numbers of this insect.

CONTROL EXPERIMENTS.

Since most of the cranberry bogs on the Pacific coast can not be provided with a sufficient supply of water for use in control work, insect pests on these bogs should be combated largely by the application of insecticides in the form of a liquid spray. This method seems especially desirable against the fireworm after a study of its habits and methods of feeding. It may also be necessary to do more or less spraying for certain fungous diseases at various times throughout the season, and some of the dates for these applications may correspond to a great extent with the time of application in the control of the fireworm. The grower, therefore, can combine the materials used for the control of the fireworm with those necessary for fungous diseases whenever the times for these two applications coincide, and thus save the expense of separate applications.

All the control experiments against the blackhead fireworm were arranged, therefore, so as to include tests under actual bog conditions of several methods of spraying the eggs, larvæ, and adults with a number of promising insecticides, both with and without spreaders, at various times throughout the season. These sprays were applied by the types of nozzles shown in figures 12, 13, and 14, all the tests being so planned as to shed some light on questions concerning the number of applications, the best materials to be used, the amount of spray material which should be used per acre, and the most effective manner of applying it.

MISCELLANEOUS SPRAYING EXPERIMENTS.

In Table 3 is given an outline and the results of the miscellaneous spraying experiments conducted on Howe vines on the Portland-Seaview Cranberry Co. bog at Seaview, Wash., in 1919. Very similar experiments were performed on this bog in 1918, but the severe infestations previous to that season had so reduced the bearing power of the vines that few blossoms were set in 1918, and the results therefore were not wholly dependable. They showed, however, a decided increase in control by the use of insecticides combined with spreaders, such as soap or glue, as compared with the same insecticides applied without the addition of these wetting agents. They also suggested that a solution of 40 per cent nicotine sulphate, used at the rate of 1 part to 1,000 parts of water, with the addition of fish-oil soap at the rate of 2 pounds to 50 gallons and applied at the rate of about 300

gallons per acre, might be just as effective as the same kind of a solution in which the nicotine was used at the rate of 1 part to 800 parts of water and applied at the rate of about 200 to 250 gallons per acre.

The miscellaneous spraying experiments conducted on this bog in 1919 were therefore planned in the light of the results of the previous season.

TIME AND NUMBER OF APPLICATIONS.

The odd-numbered plats, I to XV inclusive, received 3 applications on the dates shown in Table 3. The first application (May 13 and 14) was made to catch the largest possible number of small larvæ in and near the tips of the uprights before they had a chance to web up the new unfolding leaves. The new growth at this time was approximately three-fourths of an inch long. The second application, June 12, was made to kill the next lot of larvæ hatching after the first application and came about the time when the majority of the blossoms were in the "hook stage." In order to catch the late-hatching larvæ the third spraying was made July 1 and 2 as the vines were approaching full bloom. The even-numbered plats, from II to XVI inclusive, and plat XVII, received in addition to these applications just described one more application (July 16 and 17) about the time the moths were flying on this bog in greatest abundance. The purpose of this fourth application was to kill these moths and also any larvæ which had moved into the tips at this time.

While the frosts of May 4, 5, and 6 somewhat reduced the crop on nearly all the plats, the comparative results, as obtained by the examination of the berries from 3 circular areas of about 100 square inches, each picked at random over each of the plats, strengthen the observations made of these plats at various times throughout the season.

TABLE 3.—Outline of miscellaneous spraying experiments in the control of the blackhead fireworm on the Portland-Seaview Cranberry Co. bog at Seaview, Wash., 1919.

Plat No.	Spray materials, dosage, etc.	Number of gallons used calculated per acre per application.					Total number of berries examined.	Total number of berries free from injury.	Gain over check.
		May 13 and 14.	June 12.	July 1 and 2.	July 16 and 17.	Average per application.			
I.....	40 per cent nicotine sulphate, 1-1,000+fish-oil soap, 2-50.....	380	300	320	.....	333	388	<i>Per cent.</i> 92.52	<i>Per cent.</i> 15.50
II.....	40 per cent nicotine sulphate, 1-1,000+fish-oil soap, 2-50.....	380	300	320	480	370	402	95.52	18.50
III.....	40 per cent nicotine sulphate, 1-800 + fish-oil soap, 2-50.....	330	280	280	.....	297	735	93.74	16.72
IV.....	40 per cent nicotine sulphate, 1-800 + fish-oil soap, 2-50.....	330	280	280	480	342	737	97.42	20.40

TABLE 3.—Outline of miscellaneous spraying experiments, etc.—Continued.

Plat No.	Spray materials, dosage, etc.	Number of gallons used calculated per acre per application.					Total number of berries examined.	Total number of berries free from injury.	Gain over check.
		May 13 and 14.	June 12.	July 1 and 2.	July 16 and 17.	Average per application.			
V.....	40 per cent nicotine sulphate, 1-600 + fish-oil soap, 2-50.....	295	270	270	.....	278	820	<i>Per cent.</i> 91.21	<i>Per cent.</i> 14.19
VI....	40 per cent nicotine sulphate, 1-600 + fish-oil soap, 2-50.....	295	270	270	500	333	485	94.22	17.20
VII...	Powdered arsenate of lead, 2-50 + fish-oil soap, 2-50.	340	300	260	.....	300	401	83.04	6.02
VIII..	Powdered arsenate of lead, 2-50 + fish-oil soap, 2-50.	340	300	260	450	337	172	76.16	.96
IX....	Nicotine oleate, 1-300.....	295	270	270	.....	278	433	91.45	14.43
X.....	Nicotine oleate, 1-300.....	295	270	270	320	289	862	91.99	14.97
XI....	40 per cent nicotine sulphate, 1-800 + glue, 1-200.	290	280	310	.....	293	703	83.64	6.62
XII...	40 per cent nicotine sulphate, 1-800 + glue, 1-200.	290	280	310	620	375	600	86.16	9.14
XIII..	Nicotine oleate, 1-400.....	300	320	350	.....	323	1,012	92.29	15.27
XIV...	Nicotine oleate, 1-400.....	300	320	350	660	407	1,061	91.42	14.40
XV....	Nicotine oleate, 1-500.....	330	380	320	.....	343	753	87.64	10.62
XVI...	Nicotine oleate, 1-500.....	330	380	320	600	407	827	92.38	15.36
XVII..	"Phenol compound" No. 1, 1-500.....	420	560	320	560	460	628	73.56	3.46
XVIII	Check, untreated.....	.....	.....	.....	.....	.....	74	77.02	.....

NOTE.—Mist nozzles as shown in figure 13 used for all applications, with hand barrel spray pump giving pressure of 50 to 100 pounds.

NICOTINE SULPHATE.

The conclusions drawn by Scammell¹¹ regarding the effectiveness and safety of 40 per cent nicotine sulphate in the control of the blackhead fireworm were borne out in the work on the Pacific coast. Of the various strengths used, 1 part to 800 parts of water with 2 pounds of fish-oil soap to each 50 gallons of solution, applied 4 times, seemed to give the highest percentage of cranberries free from fireworm injury; it will be noted in Table 3, however, that 4 applications of this material, used 1 to 1,000, gave nearly as great a gain over the check. The fact that it gave a higher percentage of clean fruit than 1 to 600 was probably due to the fact that there was a larger setting of fruit on this plat and perhaps a somewhat lighter infestation than on the one treated with the solution of the strength of 1 to 600.

NICOTINE OLEATE.

Nicotine oleate was made by stirring together the proportions of a 40 per cent solution of free nicotine and oleic acid according to the directions given by Moore¹² as follows:

¹¹ Scammell, H. B. A New Method of Controlling the Blackhead Fireworm. *In Proc. 47th Ann. Conv. Amer. Cranberry Growers' Assn.* (Aug. 26, 1916), p. 8-12; Cranberry Insect Problems and Suggestions for Solving Them, U. S. Dept. Agr., Farmers' Bul. 860, p. 4-9, 1917.

¹² Moore, William. A Promising New Contact Insecticide. *In Journ. Econ. Ent.*, v. 11, no. 3, p. 341-342, 1918.

Two and one-half parts of a 40 per cent nicotine solution unites with $1\frac{3}{4}$ parts of commercial oleic acid or red oil. Four and one-fourth parts of this soap will then contain 1 part of nicotine or will equal $2\frac{1}{2}$ parts of the 40 per cent nicotine solution.

It will thus be seen that nicotine oleate is a *nicotine soap* made from a fatty acid and nicotine; as such it has the spreading properties of a soap and in addition it is a contact insecticide which can generally be used in place of the ordinary 40 per cent nicotine sulphate and soap solution for cranberry spraying. It could not be mixed, however, with *hard water* or combined with Bordeaux mixture or any other alkaline solutions; and since it takes $4\frac{1}{4}$ parts of the nicotine oleate to equal in nicotine content $2\frac{1}{2}$ parts of the 40 per cent nicotine solution, *about twice as much nicotine oleate as 40 per cent nicotine sulphate* had to be used to equal one part of the latter.

A spray material of this character, which has combined in it both soap and nicotine, would greatly facilitate the control of the fireworm, if not materially reduce the cost, wherever its use is practicable. Solutions of the strengths used seemed to spread equally well over the cranberry foliage. As shown in Table 3, it was used at the rate of 1 part to 300 parts of water, 1 to 400, and 1 to 500, about equal, respectively, to 1 to 600, 1 to 800, and 1 to 1,000 of the 40 per cent nicotine sulphate formulas. Both three and four applications were made of each strength. The largest percentage of fruit free from fireworm injury seemed to be obtained where nicotine oleate was used at the rate of 1 to 500 and applied four times. There is very little difference between the results of this plat (plat XVI) and those secured on plat XIII where nicotine oleate 1 to 400 was applied three times. This is partly explained by the fact that the fireworm infestation was more thinly scattered over the former plat than over the latter. The results where nicotine oleate was used at the rate of 1 to 300, while apparently very satisfactory, are not so good, considering all factors, as where it was used at the rate of 1 to 400.

ARSENATE OF LEAD.

As in 1918, arsenate of lead proved to be of little or no value in the control of the fireworm, the foliage being badly eaten and nearly all the berries destroyed by the worms, even where four applications were made with the addition of soap.

WETTING AGENTS OR "SPREADERS."

That the presence in the spray liquid of some material like soap, which will make it wet or spread over the smooth, waxy foliage of the cranberry, seems to make considerable difference in the control

results obtained was plainly shown by the preliminary experiments of 1918 previously referred to. In 1919, therefore, a comparison of the kinds of spreaders was made and in these tests glue, 1 pound to 200 gallons, and nicotine oleate at the strengths mentioned above were checked against fish-oil soap, 2 pounds to 50 gallons. As will be observed in Table 3, the use of glue gave the poorest control of the three groups of plats III and IV, XI and XII, and XIII and XIV, in all of which the strength of the nicotine was approximately the same; nicotine oleate was next; and fish-oil soap, 2 to 50, gave the best results.

Observations made immediately after these spreaders were applied showed that glue spread the solution fairly well over the old foliage, but failed to carry it into the small, new leaves at the tip, the region of greatest activity of the young larvæ; nicotine oleate spread very satisfactorily over both old and new foliage, but did not seem to go as far into the unfolding buds and leaves as did the solution containing fish-oil soap, which, moreover, might be one reason for the superior control secured where fish-oil soap was used as a spreader.

It was observed that fish-oil soap used at this strength would often carry the solution containing it into the very center of the group of small unfolding leaves at the tip of the upright and enable the solution to find its way into the loose web of any small larvæ which might be working therein.

"PHENOL COMPOUND No. 1."

A proprietary compound used primarily as a disinfectant and containing a large amount of crude carbolic acid was tested against the fireworm. This material mixes in all proportions with water, making a milky white solution which gives off a strong, characteristic carbolic-acid odor. It was used at the rate of 1 part to 500 parts of water and sprayed directly into the tips of the vines, as on the other plats. As will be noted in Table 3, little or no control was secured.

DEMONSTRATION SPRAYING EXPERIMENTS.

The results of a series of demonstration spraying experiments, conducted on the bogs belonging to H. M. Williams & Sons, at Ilwaco Junction, Wash., in 1919, are presented in Table 4. The material found most effective in previous tests, namely, 40 per cent nicotine sulphate, 1 to 800, with soap 2 to 50, was used in all these experiments.

TABLE 4.—Outline of spraying experiments in the control of the blackhead fireworm on the H. M. Williams & Son's bog at Ilwaco Junction, Wash., 1919.

Plot No.	Spray materials, dosage, nozzle, and variety of cranberry.	Number gallons used per acre per application.					Total number of berries examined.	Berries free from fireworm injury.		Gain over check.	Yield per acre.	Gain in yield over check.
		First, May 2-6.	Second, May 20-21.	Third, June 13-17.	Fourth, July 9-10.	Average per application.		Unfertilized and immature.	Total number free.			
A....	40 per cent nicotine sulphate, 1-800 + fish-oil soap, 2-50, mist nozzle, Howe variety.	378	378	418	.....	391	1,071	<i>Per ct.</i> 54.44	<i>Per ct.</i> 89.35	<i>Per ct.</i> 30.27	<i>Bush.</i> 31.32	<i>Bush.</i> 18.52
B....	40 per cent nicotine sulphate, 1-800 + fish-oil soap, 2-50, Bordeaux nozzle, Howe variety.	457	666	444	.....	522	1,355	58.67	89.74	30.66	46.98	34.18
C.....	40 per cent nicotine sulphate, 1-800 + fish-oil soap, 2-50, "spray gun," Howe variety.	300	389	257	417	341	1,238	62.52	93.05	38.10	56.99	40.88
D....	40 per cent nicotine sulphate, 1-800 + fish-oil soap, 2-50, "spray gun," Howe variety.	300	389	257	.....	315	1,499	54.30	84.25	29.30	75.06	58.95
E....	40 per cent nicotine sulphate, 1-800 + fish-oil soap, 2-50, "spray gun," McFarlin variety.	300	327	267	268	290	1,075	45.30	87.72	46.16	176.88	161.85
F....	40 per cent nicotine sulphate, 1-800 + fish-oil soap, 2-50, "spray gun," McFarlin variety.	300	327	267	.....	298	1,162	41.22	77.45	35.89	124.65	109.62
G....	40 per cent nicotine sulphate, 1-800 + fish-oil soap, 2-50, Bordeaux nozzle, McFarlin variety.	563	697	884	643	697	1,345	69.00	91.97	50.41	168.84	153.81
H....	40 per cent nicotine sulphate, 1-800 + fish-oil soap, 2-50, mist nozzle, McFarlin variety.	499	388	499	554	485	2,343	56.50	93.81	52.25	364.26	349.23
1.....	Check on lee of plats A and B, Howe variety, untreated (for check on plats A and B).	.....	.....	.....	.....	.....	479	44.88	59.08	.....	12.80	.....
2.....	Check on lee of plats C and D, Howe variety, untreated (for check on plats C and D).	.....	.....	.....	.....	.....	626	43.93	54.95	.....	16.11	.....
3.....	Check on lee of plats F and H, McFarlin variety, untreated (for check on plats E, F, G, H).	.....	.....	.....	.....	.....	474	33.55	41.56	.....	15.03	.....

Here an effort was made to test the three types of nozzles, namely, the Bordeaux, the mist type, and the spray gun, on as large a scale as possible, and to approach commercial spraying conditions. The plats selected ranged in approximate size from one-fourth to one-half acre and included the Howe and McFarlin varieties. These were previously badly infested with the fireworm and yielded few or no berries in 1918. Figures 12, 13, and 14 show these three types in actual use, and Table 4 shows the number of gallons per acre used in spraying with each type of nozzle, with a pressure of about 250 pounds at the tank. A stationary power outfit was used for all the applications, pipes being used to convey the spray liquid from the pump to the plats.

Plats A and B constituted one section, containing about an acre of vines, C and D another to the south, and E, F, G, and H a third to the east of C and D. Since the infestation of these three sections varied somewhat it was thought advisable to have a check plat measuring 1 by 2 rods for each section. As noted in Table 4, they were placed to leeward of the plats of which they acted as checks to prevent the unnatural spread of moths over the plats. These were numbered 1, 2, and 3, respectively.

The percentages of berries free from fireworm injury, as shown in Table 4, were obtained from an examination of the berries picked at harvest time from five circular areas of approximately 100 square inches each, selected at random on each sprayed plat. Berries were examined from three such areas on each of the check plats.

The yield of each plat was obtained by measuring its entire crop as picked at harvest time. Plats A, B, C, and D were picked with a scoop, and plats E, F, G, and H were picked by hand. The first four plats included vines of the Howe variety and the last four, vines of the McFarlin variety, all of which had reached the age of normal bearing.

TIME AND NUMBER OF APPLICATIONS.

The first three applications were made at practically the same time for all plats, since the growth of the two varieties on these plats was very much the same. The first application was made on May 2 to 6, about the time when the largest number of buds were pushing forth but had not exceeded a growth of approximately three-fourths of an inch. This was the time when the young larvæ were appearing in very large numbers but before many of them had got beyond reach of the spray.

The second application was made May 20 and 21, when many blossoms were in the hook stage, and was timed so as to catch the next lot of larvæ before they could conceal themselves in the new growth.

The third came June 13 to 17, when the vines were nearly in full bloom. It was designed to kill any late-hatching larvæ of the first generation which might have been injuring the blossoms and newly forming berries.

Plats C, E, G, and H received a fourth application on July 9 and 10 at about the time many berries were already set. This application was intended to kill any very late-hatching larvæ and the moths which appeared on the bogs in largest numbers about this time.

THE BORDEAUX NOZZLE.

The Bordeaux nozzle is modeled so as to deliver a forceful, driving spray in the shape of a fan. The nozzle is so arranged that the intensity of the fan-shaped spray can be regulated as desired. In



FIG. 12.—Bordeaux nozzle equipment used in spraying experimental plats: *a*, Nozzles held to show delivery of fan-shaped spray on a horizontal plane; *b*, nozzles held in proper position for delivering spray to vines.

spraying plats B and G with this type of nozzle, an effort was made to hit on a nearly horizontal plane the underside of all the leaves, as well as to penetrate the vines and wet thoroughly with the spray solution all parts of the uprights, including the tips, by directing a forceful stream of spray, as shown in figure 12 *b*. The main idea was to wet the eggs and also to catch the young larvæ in their burrows on the undersides of the lower leaves, as well as to wet any larvæ in the tips at the time.

As will be observed in Table 4, three applications with this nozzle on Howe vines in plat B at an average rate of 522 gallons per acre resulted in a gain in yield of 34.18 bushels per acre over the untreated plat; 89.74 per cent of the berries examined from this plat were free from injury by the fireworm. On the McFarlin vines in plat G four applications at an average rate of 697 gallons per acre, with this type of nozzle, produced a gain of 153.81 bushels per acre over the check and 91.97 per cent of the sample berries were free from fireworm injury. The small yields of plats A and B were due largely to the fact that since the vines in this section had been very badly infested the previous season, they produced very scanty bloom, and they also appeared to suffer more from frost on May 4, 5, and 6 than the other plats.

THE MIST NOZZLE.

The mist nozzle used was of the eddy-chamber or whirlpool-disk type, somewhat larger than the Vermorel and without the center-cleaning punch of the latter. It is so constructed internally as to throw a medium fine mist in the form of a hollow cone of spray which, depending upon the pressure of the liquid, measures from 12 to 18 inches in diameter about a foot from the nozzle. The outfit, as shown in figure 13, was made from galvanized iron pipe one-fourth to three-eighths of an inch in diameter on which four nozzles were placed 11 inches apart and the whole attached to the end of an ordinary 8 or 10 foot bamboo spray pole. The first nozzle on the end was set close to the pipe and each succeeding one was set 1 inch farther away than the preceding so that all would be the same distance from the vines when the rod was held by the operator in proper position for spraying.

The applications with this type of nozzle on plats A and H were made with the primary idea of filling the terminal whorl of old leaves and the new unfolding leaves at the tip of the upright with the nicotine sulphate and soap solution. As will be seen in figure 13, this spray was delivered on a more or less vertical plane, and no special effort was made to hit the underside of the leaves, entire dependence being placed on a thorough soaking of the tips of the uprights, which was quickly and easily done with this type of nozzle.

On the Howe vines in plat A, three applications, at an average rate of 391 gallons per acre, with the mist nozzle produced a gain in yield of 18.52 bushels per acre over the check; 89.35 per cent of the berries picked from sample areas were free from fireworm injury. On the other hand, the same type of nozzle used on McFarlin vines in plat H, with four applications at the rate of 485 gallons per acre, produced a gain over the untreated vines in this section of 349.23 bushels per acre, 93.81 per cent of the berries examined being free from fireworm injury.

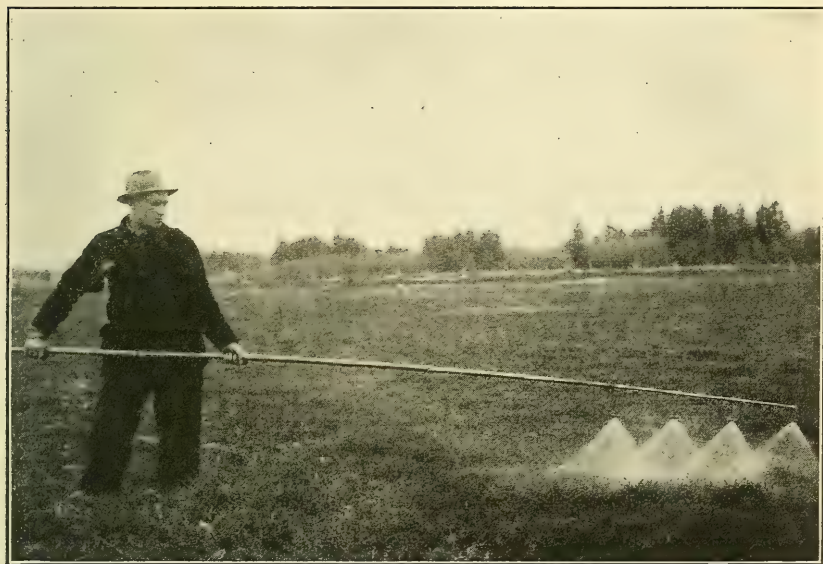


FIG. 13.—Mist nozzle equipment used in spraying experimental plats.

THE SPRAY GUN.

The spray gun (fig. 14) comprises usually a very large nozzle of the eddy-chamber type attached to a piece of tubing of varying length, fitted with a device for regulating at will the size and volume of the spray delivered through the nozzle. It is of larger capacity than the ordinary mist nozzle of the eddy-chamber type and is intended to be used only on power outfits where the pressure can be maintained at 200 pounds or over. In these experiments this type of nozzle was used at full-capacity opening with a medium-sized disk and threw a stream of spray about 15 to 20 feet long, which broke up into a medium fine mist before it reached the vines.

In the use of the spray gun on plats C, D, E, and F an effort was made to fill the tips of the uprights with the spray liquid and also to hit the undersides of the leaves by holding the nozzle close enough to the vines so that the liquid would be delivered on a nearly horizontal

plane. In this position the uprights would be bent over slightly and the tips as well as some of the lower leaves given a thorough wetting.

As seen in Table 4, three applications with this type of nozzle on the Howe variety (plat D) resulted in an increase of 58.95 bushels per acre over check, and 84.25 per cent of the berries examined were free from fireworm injury. Four applications on the same variety on the adjoining plat (plat C) resulted in a gain in yield of only 40.88 bushels over the check, doubtless because of the thin setting of blossoms on this plat, but 93.05 per cent of the fruit examined from the sample areas was free from fireworm injury.



FIG. 14.—Spray-gun used in spraying experimental plats. Shows size of stream of spray used, with medium-sized disk at full capacity.

On the McFarlin variety (plat F) three applications gave a gain of 109.62 bushels per acre over the untreated vines, 77.45 per cent of the examined fruit being free from fireworm injury. Four applications (plat E) gave better results, a gain of 161.85 bushels over the untreated vines, 87.72 per cent of the examined fruit being sound.

THE THREE TYPES OF NOZZLES COMPARED AS TO ECONOMY OF TIME AND MATERIAL.

With the Bordeaux outfit (fig. 12) it took about $1\frac{1}{2}$ hours to spray an acre, an average of 609 gallons being necessary for a thorough application. It was necessary to walk about 24 times across the acre, which was in the form of a square. With the mist outfit (fig. 13), it took about 1 hour to spray an acre, 438 being the average

number of gallons used for a thorough application. Approximately 12 trips were necessary across an acre with this outfit. In point of time and material the spray gun was the most economical, requiring only 35 or 40 minutes to spray an acre, with an average of 375 gallons for an application. It was necessary to make only 6 to 8 trips with one spray gun across an acre.

EFFECT OF THE NICOTINE-SULPHATE-AND-SOAP SOLUTION ON THE CRANBERRY PLANT.

Although 40 per cent nicotine sulphate in the proportion of 1 part to 800 parts of water with fish-oil soap at the rate of 2 pounds to each 50 gallons of solution was applied to the vines when they were almost in full bloom, no decided decrease in the setting and maturity of the berries seemed to occur on those plats on which the spray was not applied forcefully or on a nearly horizontal plane. It will be noted, however, in Table 4 that the percentage of unfertilized and immature berries, i. e., the very small, dried, and undeveloped ones, but which were free from fireworm injury, was slightly, and in some cases considerably, increased in all the sprayed plats except F as compared with the respective untreated ones, the three plats with the highest percentage of berries of this kind being plats B, C, and G. Some explanation of this may possibly be found in the fact that in two of these plats, namely, B and G, the spray was applied forcefully with the Bordeaux nozzle on a nearly horizontal plane, which probably could have seriously affected the fertility of the blossoms, as in some cases they were almost blown from the uprights. Plat C received four rather forceful applications with the spray gun, and this also may in a measure account for the high percentage of unfertilized berries picked from this plat.

It is generally recognized among cranberry growers and others familiar with cranberry culture that the presence of a large amount of wet weather during the blooming period sometimes results in a small crop of berries. Whether or not the wet weather causes a decreased crop by preventing the ordinary pollenization by insects or by destroying the fertility of some blossoms still seems to be a matter of conjecture. Since all the plats were affected by the same set of natural conditions, however, it would seem logical to suppose that the spraying of the vines while the blossoms were open with a type of nozzle which delivered a forceful spray on a more or less horizontal plane, and which thus thoroughly wet the floral organs, might have caused the comparatively small crop on the plats thus treated, by the sterilization and mechanical destruction of the blossoms.

On the other hand, a certain rather beneficial effect in addition to the control of the fireworm was observed from the use of the nicotine-sulphate-and-soap solution, especially on the McFarlin variety. On

plats E, F, G, and H, but particularly on H, it was noticed that the berries were generally much larger and the vines of a brighter green than those on the other plats. Wherever this spray solution was used it seemed to have a fertilizing or stimulating effect on the vines, making them grow more luxuriantly and produce larger sized berries than they otherwise would have done.

RECOMMENDATIONS FOR CONTROL.

REFLOWING.

As recommended by Scammel,¹³ reflowing, where it is possible to do it properly, will doubtless be as effective in controlling the black-head fireworm on the Pacific coast as elsewhere. While no experiments were performed along this line on the Pacific coast, yet for the benefit of those growers who may be able to equip their bogs for reflowing and wish to employ this method of control, it might be stated that the proper time to reflow for the fireworm is when the majority of the larvæ of the first brood are about full grown, as at this time they can be more easily and quickly killed than in any other stage.¹⁴ On the bogs in the vicinity of Seaview, Wash., the majority of the larvæ of the first brood are full grown near the middle or latter part of May, but if the bog is winter flowed, i. e., covered with water in the wintertime, this date would vary according to the date this winter flood was drawn from the bog. In reflowing, the water should completely cover the vines and be held there for at least 48 hours in order to kill the greatest number of larvæ. Any grass or other objects projecting above the surface should be removed so that the larvæ can not crawl up to the tops and thus escape the flood.

SPRAYING.

Spraying with a solution of 40 per cent nicotine sulphate and water, with soap as a spreader, has been found to be the most effective method of controlling the blackhead fireworm on the Pacific coast.

HOW TO PREPARE THE NICOTINE SULPHATE SPRAY.

Any nicotine solution containing 40 per cent of nicotine sulphate is suitable in the preparation of this spray, and any kind of soap *free from uncombined oils or greases* may be used as a spreader. The proportions found most effective against the fireworm are: One part of 40 per cent nicotine sulphate to 800 parts of water, with 2 pounds of soap to each 50 gallons of the liquid. Solutions containing a greater proportion of nicotine sulphate than 1 to 800 will do no

¹³ Scammel, H. B. Cranberry Insect Problems and Suggestions for Solving Them. U. S. Dept. of Agr., Farmers' Bulletin 860, p. 7-8. 1917.

¹⁴ Ibid, p. 8.

harm, but on the other hand will give no better control, and if used at the rate of 1 part to 1,000 parts of water with the above proportion of soap, about one-third to one-half more gallons per acre should be used and then only on light infestations.

To make 200 gallons of this material the tank should be run about three-fourths full of water while washing through the sieve 8 pounds of the soap, which should be previously broken up in warm water or otherwise thoroughly softened. One quart of the 40 per cent nicotine sulphate should then be poured slowly into the tank with the remainder of the water necessary to make up the 200 gallons while the whole solution is being thoroughly agitated to insure proper mixing of the ingredients. It is then ready to be applied to the vines.

The nicotine sulphate is added last and in a diluted form to prevent the precipitate which forms when concentrated solutions of nicotine sulphate and soap are brought together and which decreases the effectiveness of the spray solution.

If these materials are to be combined with Bordeaux mixture, the proportions of nicotine sulphate and soap and the process of mixing is the same as though water were used to make the solution as described above. Nicotine sulphate can be mixed with lime-sulphur solutions in all the usual proportions, but *no soap should be added to a solution containing lime-sulphur or any other similar compound*, else a disintegration of the ingredients will take place which will not only weaken the effectiveness of the combination but also may cause severe injury to the cranberry vines.

THE AMOUNT TO BE USED PER ACRE.

Depending on the severity of the infestation, not less than 250 to 300 gallons of this solution should be used in spraying an acre of vines, as good control can not usually be secured with a less amount than this. If it is preferred to use 40 per cent nicotine sulphate at the rate of 1 to 1,000, rather heavy applications will have to be made, less than 400 or 500 gallons per acre never being used.

TYPE OF NOZZLE.

The use of a nozzle, preferably of the large eddy-chamber type shown in figure 13, equipped with a disk, throwing a *medium-fine* mist which will quickly and easily wet the terminal whorl of leaves on the tip of the uprights, is to be recommended. The Vermorel type of nozzle is too small and throws too fine a mist (fig. 15), most of which is driven away by the wind and thus fails to give the desired results. The spray gun should be used only on very large and thinly infested bogs and then great care must be taken to see that no uprights are missed and that a uniform application is made with the pressure at the tank never less than 200 pounds per square inch.

PRESSURE.

The pressure need not be higher than about 200 or 250 pounds at the tank, depending upon the size and length of pipe or hose through which the liquid has to be forced and the number and kind of nozzles used.

TIME AND NUMBER OF APPLICATIONS.

For vines which are only lightly infested three applications are recommended. The *first* of these should come when the new upright growth is from one-half to three-fourths of an inch long; that is,

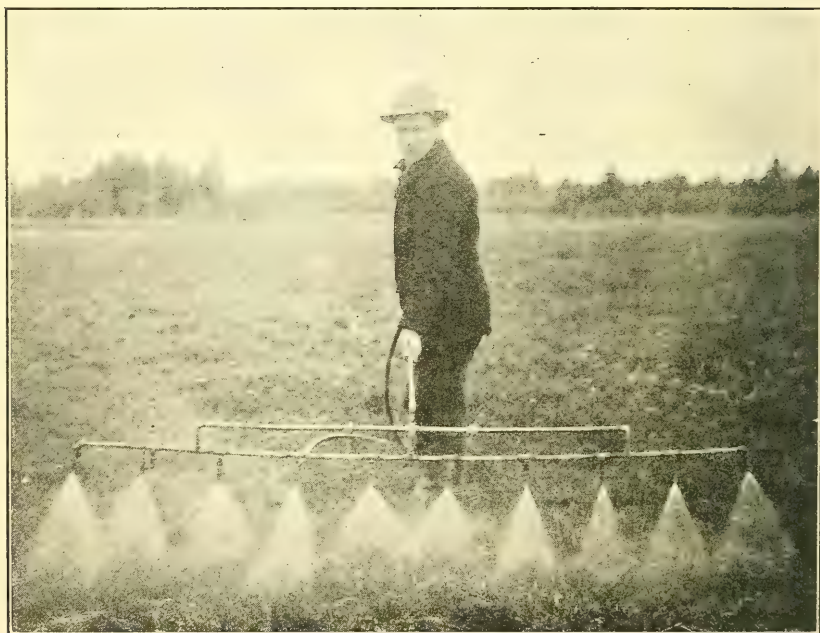


FIG. 15.—A spray boom for holding 10 Vermorel nozzles. Note the unevenness of the spray cone and the necessity of considerable walking and dragging of hose over vines in spraying. Not a good type of outfit to use.

when large numbers of the young larvæ are proceeding to and some working in or near the new unfolding leaves at the tips of the uprights. The *second* should be applied shortly after the first blossoms appear, or, in other words, at the early "hook stage." This may come from 10 days to 3 weeks after the first application, depending on the weather; it is designed to kill the next group of larvæ before they conceal themselves in the new growth. The *third* application should be made when the vines are in full bloom, or about 2 weeks after the second application, the object being to keep the young larvæ from destroying blossoms and newly forming berries.

Vines which are rather heavily infested will require the first year all three applications, as outlined above, and an additional *fourth* application, which should be made during the first two weeks of July. This last spray is designed to give protection, both to the berries and to the upright tips in which the fruit buds for the following year's crop are forming, against late hatching larvæ of the first generation and the first larvæ of the second generation. It is also designed to kill many of the moths of the first generation, and it should, therefore, be timed so as to come within the limits mentioned, as it is about this time that the moths are flying in largest numbers. By careful spraying with an outfit like that shown in figure 13, one application at this time will clean a bog of fireworm moths and thus prevent a large number of the eggs of the second generation from being deposited.

KIND OF EQUIPMENT.

A 50-gallon wheel-barrel outfit, with a strong pump, will usually be found sufficiently large for bogs up to several acres in extent. For larger bogs the power outfits of various sizes will be most economical, and in order to avoid dangerous delays at spraying time one should be sure that the parts are not only durable but easily accessible and replaceable as well.

Any arrangement of nozzles and manner of spraying the bog that will insure thorough application of the spray as previously outlined and at the same time cause a minimum injury to the vines from walking or dragging the hose over them will be satisfactory.

After a consideration of the factors which influence the hatching and development of the blackhead fireworm (see pages 8-9), it would seem reasonable to suppose that a covering of water held over the vines until late in the spring, say until about April 10 to 15, together with the thinning out of thickly vined bogs, would have a very beneficial effect. It would also facilitate good control work by grouping the hatching of the larvæ. In view of the fact that it is also considered a good horticultural practice on the Pacific coast, this method of bog management in connection with spraying is to be recommended wherever it is practicable, especially on bogs which are badly infested with fireworms.

SUMMARY AND CONCLUSIONS.

The blackhead fireworm (*Rhopobota naevana* Hübner) is the most important pest of the cranberry on Pacific coast bogs. It is found also on native cranberry vines well isolated from cultivated bogs, but was doubtless introduced on these cultivated bogs on cuttings from eastern cranberry districts. So far as known on the Pacific coast, it feeds only on the cranberry.

The phenology of the cranberry in that locality is quite variable. Usually on the earliest varieties, such as the McFarlin and Early Black, buds begin to break and the new growth begins to push forth about the beginning of April. The new upright growth is about three-fourths of an inch long by the middle of April, the blossoms are in the "hook stage" in about a month more, and full bloom comes about the beginning of June. The late varieties, such as the Howe, are more variable, but the new growth starts the beginning of May and attains three-fourths of an inch in about a week. The majority of the blossoms are in the "hook stage" about the middle of June and fully opened by the latter part of June or early July.

Almost none of the bogs on the Pacific coast are ever completely covered with water, and the seasonal temperature is comparatively equable. These conditions, coupled with the small number of parasites, enable this pest to be very destructive, the larvæ feeding on the buds, foliage, blossoms, and fruit throughout the growing season.

The insect passes the winter in the egg stage. The eggs are quite small, smooth, and slightly oval, with the center slightly raised or rounded. They are lemon and orange yellow and are deposited singly or in small irregular groups on the undersides of the cranberry leaves. The young larva on hatching leaves the egg through a rent near the edge of the upper side and then feeds for a few days on the leaf or leaves near by. Later it proceeds to the tip of the upright, there feeding on the unfolding buds and blossoms.

By rearing the insect from the egg stage in an outdoor shelter where conditions were maintained which approached those naturally found on the cranberry bog, it was found that there are annually two full generations and sometimes a partial third. Temperature, depth of vines, and drainage are the three most important factors in the hatching and development of the fireworm.

The mature larva is very active, is about one-fourth of an inch long, dark greenish yellow, with a coat of dark olive-green above, and with head and thoracic shield varying from light brown to black. The ravages of the larvæ result in a burnt appearance of the vines, as if a fire had swept over the bog. Hence the common name "blackhead fireworm."

Nearly all the larvæ change to pupæ in loosely constructed cocoons in old leaves and trash beneath the vines. The pupa is a little less than one-fourth of an inch long and of a brownish amber color.

The adult or moth moves in quick, jerky flights, is about the same length as the mature larva, and has characteristic markings of a single row of short, alternating brownish and silver-gray bars running diagonally to the front margin of the first pair of wings. The males have an irregular dark area near the front margin on the underside of the second or lower pair of wings.

Naturally the moths do not migrate more than a few yards, but, helped by a strong wind, it is possible for them to be carried as far as several hundred feet at a flight. In the egg stage, the fireworm can be disseminated over a bog in two other ways—namely, on leaves floating on the water which naturally gathers on the bog in the winter time and on leaves on cuttings used in planting.

Egg laying usually commences from one to several days after copulation and closely follows the temperature, the largest number being deposited between 3 and 9 p. m.

The larvæ of the first generation appear on the bogs in greatest abundance about the latter part of May, the pupæ toward the middle of June, and the moths about the first or second week in July.

A fungous disease which attacks the pupæ in their cocoons in the old leaves beneath the vines is responsible for the death of a large number, especially on old and badly infested bogs. Spiders and ladybird beetles also kill a large number of the fireworm moths and larvæ.

Control experiments seeking to establish the best kind of spray materials, the proper number of applications, and the most effective manner of applying them, were conducted on small and large scales under natural bog conditions. Forty per cent nicotine sulphate at the rate of 1 part to 800 parts of water, with the addition of fish-oil soap at the rate of 2 pounds to every 50 gallons, used at the rate of about 300 gallons to the acre, was found to be the most effective spray material against the fireworm. Forty per cent nicotine sulphate, used at the rate of 1 part to 1,000 parts of water with the addition of fish-oil soap, 2 pounds to every 50 gallons, was nearly as effective.

Nicotine oleate made by mixing $2\frac{1}{2}$ parts of a solution containing 40 per cent *free nicotine* with $1\frac{3}{4}$ parts of commercial oleic acid, or red oil, and used at the rate of 1 part to 400 parts of water, applied three times at the rate of about 300 to 400 gallons per acre, was found nearly as effective as 40 per cent *nicotine sulphate* 1 to 800 with fish-oil soap 2 to 50, applied three times at the minimum rate per acre. Arsenate of lead proved of little or no value in the control of the fireworm. Fish-oil soap, 2 pounds to 50 gallons of solution, was a much better spreader for spray solutions on cranberry foliage than glue, which was used at the rate of 1 pound to 200 gallons. One compound containing a high percentage of crude carbolic acid and usually employed as a disinfectant gave little or no control.

Demonstration spraying experiments were conducted in which 40 per cent nicotine sulphate 1 to 800, with fish-oil soap 2 pounds to 50 gallons, was used. Four applications on McFarlin vines, in which the eddy-chamber mist type of nozzle was used, gave the best results, producing the largest yield of berries and the highest percentage of berries free from fireworm injury.

The spray gun, used in spraying McFarlin vines four times, gave the next highest yield, but the third highest percentage of uninfested fruit of this variety.

The results of four applications with the Bordeaux type of nozzle on the McFarlin variety ranked third in yield and second in percentage of uninfested McFarlin berries.

No very definite conclusions based on yield can be drawn from the experiments of spraying on the Howe variety on account of injury by the fireworm on the plats in 1918 and frost in the spring of 1919. Of the Howe plats receiving three applications, however, the one sprayed with the Bordeaux type of nozzle resulted in the highest percentage of fruit free from fireworm injury, that sprayed with the mist type of nozzle was second, and that with the spray gun was third.

Four applications with the spray gun on the Howe variety gave the highest percentage of uninfested fruit of all the plats on which the spray gun was used.

Generally speaking, four applications gave better results than three.

On bogs that can be reflowed, a complete covering of the vines with water for not less than 48 hours during the middle or latter part of May is recommended as a help in the control of the fireworm. Since most of the bogs on the Pacific coast, however, are managed as dry bogs, spraying with 40 per cent nicotine sulphate 1 to 800, with the addition of fish-oil soap at the rate of 2 pounds to every 50 gallons, is recommended as the most feasible method of control of the black-head fireworm in that locality.

Between 250 and 300 gallons of this material should be used per acre. In making up the nicotine sulphate spray, the fish-oil soap should be mixed with about half the quantity of water and the required amount of nicotine sulphate added with the remainder of the water to prevent the formation of a precipitate which decreases the effectiveness of the spray solution and which might also clog the nozzles and possibly injure the vines. This spray solution can be combined with Bordeaux mixture or lime-sulphur in the usual proportions, in which case the process of mixing is the same as though water were used. *No soap, however, should be added if the mixture contains lime-sulphur.* The large eddy-chamber type of nozzle, throwing a medium fine mist, at a pressure of about 200 pounds at the tank, should be used; other types of nozzles may not only give unsatisfactory results but may also injure the blossoms. The spray gun should be employed only on lightly infested bogs.

Vines which are lightly infested should have three applications of the nicotine sulphate spray, the first one when the new upright growth has reached a length of about three-fourths of an inch, the second when the blossoms are in the early "hook stage," and the third when the vines are in full bloom.

Heavily infested vines should have all of these three applications at the times mentioned and an additional fourth application during the first two weeks of July. In the application of this last spray an effort should be made to hit as many moths as possible with the spray solution.

A 50-gallon barrel outfit on wheels, with a strong pump, will be found desirable for small bogs. For bogs larger than several acres in area, power outfits should be used.

In making the applications great care should always be exercised to prevent injury to the vines.

SYSTEMATIC DESCRIPTION OF RHOPOBOTA NAEVANA HÜBNER.

By CARL HEINRICH, *Bureau of Entomology.*

SYNONYMY.

Tortrix naevana Hübner, in *Samm. Eur. Schmiett.*, v. 5, Tort., pl. 41, fig. 261, 1814.

Tortrix unipunctana Haworth, in *Lep. Brit.*, p. 454, 1812.

Lithographia geminana Stephens, in *List Brit. Mus.*, Pt. X, Lep., p. 99, 1852.

? *Sciaphila luctiferana* Walker, in *Cat. Brit. Mus.*, Lep., ser. 6, pt. 28, p. 342, 1863.

Anchylopera vacciniana Packard, in *Guide Stud. Ins.*, p. 338, 1869.

Rhopobota naevana Staudinger and Rebel, in *Cat. Lepidop.*, Aufl. 3, theil 2, p. 127, 1901.

Eudemis vacciniana Dyar, in *List No. Amer. Lepidop.*, p. 466, no. 5238, 1902.

Rhopobota naevana Dampf, in *Iris*, bd. 21, p. 304-329, 1908.

GENERAL CHARACTERS.

ADULT.

Plate I, A; Plate II, A, B, C.

Thorax smooth. Forewing smooth; termen deeply concaved between veins 4 and 6; apex pointed but not falcate; 12 veins; 7 and 8 stalked; 10 from cell midway between 9 and 11; 9 approximate to 8; 11 from cell at or just before middle of cell; upper internal vein of cell nearly obsolete, when distinguishable, from between 9 and 10; 3, 4, and 5 closely approximate at termen; 2 bent up slightly at outer third; costal fold in male absent. Hindwing with 8 veins; 6 and 7 approximate toward base; 3 and 4 stalked; male with a shading of coarse black scales on underside of wing along upper vein of cell. Male genitalia as figured; harpes undivided, with rudimentary clasper present and on outer surface just above lower margin a row of rather long, stout spines; uncus present, bifurcate, arms widely separated, rather short, weakly chitinated and slipper shaped; gnathos reduced and fusing with socii; socii greatly developed, porrected, extremities meeting in hairy knoblike projection; aedoeagus straight, moderately long, fairly stout.

PUPA.

Plate I, B, C.

Slender, abdominal segments gradually tapering; a double row of spines on dorsum of abdominal segments 3 to 6 inclusive, a single row on abdominal segments 2, 7, 8, 9, and 10; first abdominal segment smooth; wings extending to or slightly beyond ventro-caudal margin of fourth abdominal segment; cephalic end bluntly rounded; vertex distinct, as broad as prothorax; labrum, mandibles, and maxillary palpi well developed; maxillary palpi extending to proximo-lateral angles of maxillae; maxillae less than half the wing length; labial palpi half the length of maxillae; prothoracic femora and mesothoracic

coxæ exposed; antennæ and mesothoracic legs not reaching to end of wings; several strong setæ on tenth abdominal segment; a pair of stout setæ on each side of anal rise; anal rise unarmed; body setæ otherwise weak and hardly distinguishable; spiracles slightly reduced; anal and genital openings slitlike in both sexes; cremaster absent.

LARVA.

Plate II, D; Plate III, A-C, E-G.

Cylindrical, slender, very slightly tapering at caudal end. No secondary hair. Legs and prolegs normal. Crochets uniordinal, in a complete circle. Anal fork present, reduced. Prothoracic shield broad, divided. Spiracles round, moderate; that on eighth abdominal segment slightly higher than those on abdominal segments 1 to 7, not over one and one-half times as large, same size as that on prothorax. Skin evenly and appreciably scobinate.

Body setæ moderately long; tubercles broadly chitinized; IV and V on abdominal segments 1 to 8 under the spiracle and approximate; prespiracular shield of prothorax elongate, large, bearing three setæ (III, IV, and V) in a longitudinal line; group VI bisetose on prothorax, unisetose on mesothorax and metathorax, greatly reduced and closely approximate to IV and V on abdominal segment 9; III antero-ventrad of the spiracle on eighth abdominal segment, directly over the spiracle on abdominal segments 1 to 7; IIIa not distinguishable; on thoracic segments 6 setæ in group VII; VII bisetose on abdominal segments 7, 8, and 9; ninth abdominal segment with 9 setæ in a nearly vertical line, paired setæ of group II close together on same chitinization on dorsum, I and III closely approximate; on abdominal segments 1 to 8 II latero-caudad of I; prothorax with II^a slightly higher than I^a, closer to II^b than to I^a, II^b above the level of puncture z; I^b nearer to puncture z than to I^c, II^c about equidistant from I^b and I^c, puncture y directly caudad of I^a, puncture x dorso-caudad of I^a and on the level of II^a.

Head capsule spherical, nearly square in outline viewed from above; slightly wider than long; greatest width well back of middle of head; incision of dorsal hind margin slight, about one-fourth the width of the head; distance between dorsal extremities of hind margin about half the width of the head. Frons broad, triangular, longer than wide, reaching beyond middle of the head. Adfrontal sutures extending to incision of dorsal hind margin. Longitudinal ridge very short, less than one-third the length of the frons.

Ocelli six; lenses well defined.

Epistoma normal.

Frontal punctures close together; well forward of frontal setæ; distance from frontal seta (F¹) to first adfrontal seta (Adf¹) about equal to distance separating adfrontal setæ (Adf¹ and Adf²); Adf² anterior to beginning of longitudinal ridge; puncture Adf^a between and about equidistant from Adf¹ and Adf².

Epicranium with the normal primary setæ and punctures and with a row of three ultraposterior setæ and one puncture. Anterior setæ (A¹, A², and A³) in a line with lateral setæ (L¹); anterior puncture (A^a) closely approximate to and posterodorsad of A². Posterior setæ (P¹ and P²) and puncture (P^b) in a line with first adfrontal seta (Adf¹); P¹ about middle of head, on the level of adfrontal puncture and lateral seta (L¹); P^b between and about equidistant from P¹ and P²; puncture P^a lying between P¹ and L¹, approximate to the latter. Lateral puncture directly posterior to L¹, remote. Ocellar setæ (O¹, O², O³) well separated, forming a right angle; O¹ lying below and between ocelli II and III; O² postero-ventrad of ocellus I, in a line with ocelli I and II

and seta A^1 ; O^3 ventrad of O^2 , remote; ocellar puncture not distinguishable. Subocellar setae (SO^1 , SO^2 , and SO^3) triangularly placed; puncture SO^3 approximate to and equidistant from SO^2 and SO^3 . Genal puncture (G^1) anterior to the seta (G^1).

Labrum with median incision broadly triangular, rather shallow; median setae (M^1 , M^2 , M^3) triangularly placed; M^2 postero-laterad of M^1 and closer to M^1 than to M^3 ; La^1 directly posterior of and approximate to La^2 , behind the level of M^2 ; La^2 on the level of M^1 ; La^3 and M^3 on the same level near anterior margin of labrum; puncture approximate and posterior to M^1 .

Epipharyngeal shield narrowly bordering the median incision, not sharply defined. Epipharyngeal setae triangularly grouped, rather close together, narrow, moderately long. Epipharyngeal rods indicated only by their short posterior projections.

Eggs.

Plate III, D.

Oval, flat, scale-like, iridescent; deposited singly.

SPECIFIC DESCRIPTION.

ADULT.

Palpi brownish on outer sides, grayish white on inner and upper sides. Face and head grayish, more or less suffused with fuscous. Thorax fuscous. Forewings grayish, cross-marked with fuscous or, in some specimens, dark reddish brown; the brown area forming an outwardly angulated basal patch somewhat marked with gray or whitish scales and covering the basal third of the wing; a similar brown suffusion forming an ill-defined fascia extending from just beyond middle of costa to tornus, considerably wider on dorsum than on costa; a narrow brown terminal line, following the contour of termen and broadening at apex to a distinct brown spot; a fainter angulate brown line from costa dividing the ocellus; on costa six or seven pairs of short, somewhat obscure, white geminate marks separated by distinctly brownish shadings; ocellus metallic gray with longitudinal markings. Hindwings fuscous. Legs fuscous with inner sides white or grayish and tarsi annulated with white. Alar expanse, 9-14 mm.

PUPA.

Length, 5-6 mm.; yellow or yellowish brown, not appreciably darker at extremities but with sutures and caudal margins of abdominal segments brown; dorsal abdominal spines brown, arranged as shown in Plate I, C.

LARVA.

When full grown, 10-11 mm. long by 1 mm. broad. Body sordid white; the scobination blackish, giving the entire larva a pale smoky fuscous color; chitinized areas about body tubercles white except on prothorax where they are dark brown, in some specimens almost black; thoracic shield brown or blackish brown; median dividing line pale yellow; chitinized parts of thoracic legs black or blackish brown; anal shield yellowish; anal fork two-pronged, small and easily overlooked; body hairs brown; crochets 36-42, brown, weaker at the cephalic end of the circle and increasing in length toward the caudal margin where the longest are over twice as long as the shortest at the anterior margin (Pl. III, C). Head yellow, more or less suffused with dark brown, especially on ventral side; a distinct brownish patch at posterior lateral angle of epicranium; chitinized parts of trophi black or blackish brown; ocellar pigment black, continuous under the ocelli; lenses white.

EGG.

Shining grayish white; entire surface finely and evenly faceted, smooth.

This species has appeared in our economic literature and lists under the name *vacciniana* Packard, and has been held to be an American species distinct from the European *naevana* Hübner, although the synonymy has been long suspected. A careful comparison of the genitalia and external characters of the two shows them to be one species. Another American species, *Epinotia ilicifoliana* Kearfott, also should be referred to the genus *Rhopobota* as a variety of *R. naevana*. In genitalia it is identical but differs somewhat in pattern. Dampf, in a very excellent study of their genitalia, has shown the synonymy of the two European forms *naevana* Hübner and *geminana* Stephens.

The larva of *Rhopobota naevana* is easily confused with another cranberry feeder, *Peronea minuta* Robinson, which it superficially resembles. The latter, however, can be at once distinguished by the arrangement of setæ I, II, and III on the ninth abdominal segment and its different anal fork. In *R. naevana* I and III are closely approximated and on a single chitinization and the anal fork is two-pronged and very small; whereas in *P. minuta* I is well separated from III, about equidistant from both II and III, and both I and III are on separate chitinizations and the anal fork is five or six pronged, large, and rather conspicuous.

EXPLANATION OF PLATES.

PLATE I.

Rhopobota naevana:

A.—Adult.

C.—Pupa, dorsal view.

B.—Pupa, ventral view.

Explanation of symbols applied to pupa.

a = antenna.	l ³ = metathoracic leg.
ao = anal opening.	lp = labial palpi.
at = invaginations for anterior arms of tentorium.	md = mandible.
cx ² = coxa of mesothoracic leg.	mp = maxillary palpus.
es = epicranial suture.	ms = mesothorax.
f ¹ = femur of prothoracic leg.	mt = metathorax.
ge = glazed eyepiece.	mx = maxilla.
go = genital opening.	p = prothorax.
lb = labrum.	se = sculptured eyepiece.
l ¹ = prothoracic leg.	v = vertex.
l ² = mesothoracic leg.	1 to 10 = abdominal segments 1 to 10.

PLATE II.

Rhopobota naevana:

A.—Denuded forewing of female moth, showing venation.

B.—Denuded hindwing of female moth, showing venation.

C.—Male genitalia of moth; ventral view of organs spread.

D.—Setal map of first and second thoracic, and third, eighth, and ninth abdominal segments of larva, showing arrangement of body setæ.

Explanation of symbols applied to genitalia.

Ae = ædœagus.	Hp = harpe.
An = anellus.	Si = socii.
Cl = clasper.	U = uncus.
Cn = cornuti (spines on penis).	Vm = vinculum.
Gn = gnathos.	

PLATE III.

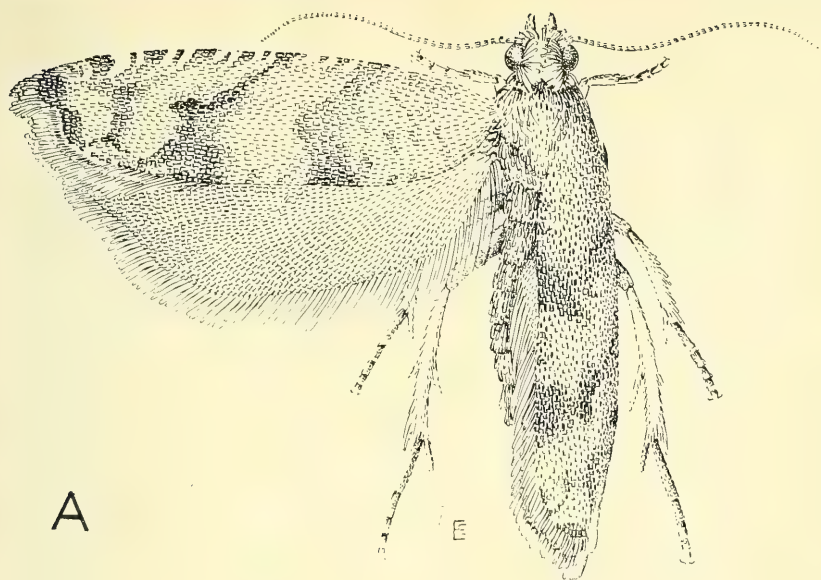
Rhopobota naevana:

- A.—Dorsal view of head capsule of larva, showing setal arrangement.
 B.—Lateral view of head capsule of larva, showing setal arrangement.
 C.—Arrangement of crochets of abdominal proleg of larva.
 D.—Egg, greatly magnified.
 E.—Ventral view of tenth abdominal segment of larva, showing anal fork.
 F.—Labrum of larva.
 G.—Epipharynx of larva.

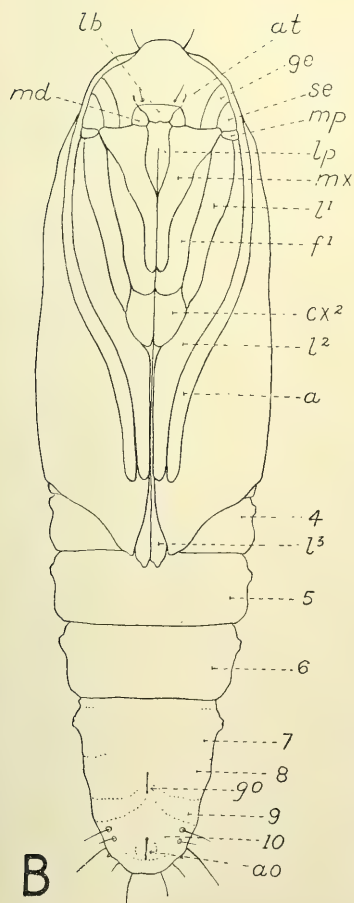
Explanation of symbols applied to larva.

- A¹, A², A³, A^a=setæ and puncture of anterior group of epicranium.
 Ad^{r1}, Ad^{r2}, Ad^{ra}=adfrontal setæ and puncture of epicranium.
 ADFR=adfrontal ridge of larval head.
 ADFS=adfrontal suture of larval head.
 Af=anal fork.
 E¹, E²=epistomal setæ.
 ER=epipharyngeal rod.
 ES=epipharyngeal shield.
 ET=epipharyngeal setæ.
 F¹, F^a=frontal seta and puncture of epicranium.
 FR=frons of epicranium.
 G¹, G^a=genal seta and puncture of epicranium.
 L¹, L^a=seta and puncture of lateral group of epicranium.
 La¹, La², La³=lateral setæ of labrum.
 Lp=labral puncture.
 LR=longitudinal ridge of epicranium.
 M¹, M², M³=median setæ of labrum.
 O¹, O², O³=setæ of ocellar group of epicranium.
 P¹, P², P^a, P^b=setæ and punctures of posterior group of epicranium.
 SO¹, SO², SO³, SO^a=setæ and puncture of subocellar group of epicranium.
 X=ultraposterior setæ and puncture of epicranium.

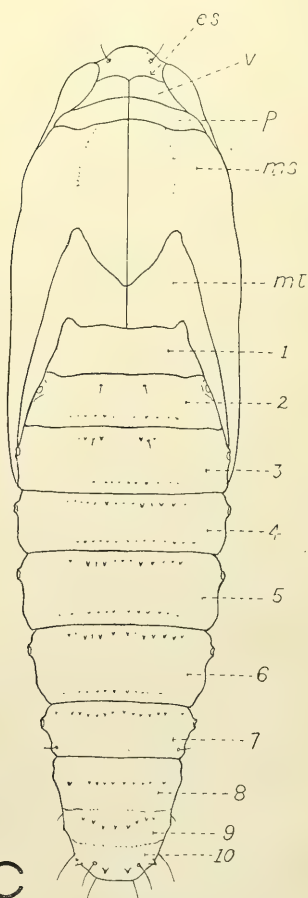
Drawings on Plates I, II (except C), and III were made under the author's supervision by Miss E. Edmonston, of the Bureau of Entomology. The male genitalia (Pl. II, C) were drawn by Miss Ada F. Kneale, formerly of the Bureau of Entomology.



A

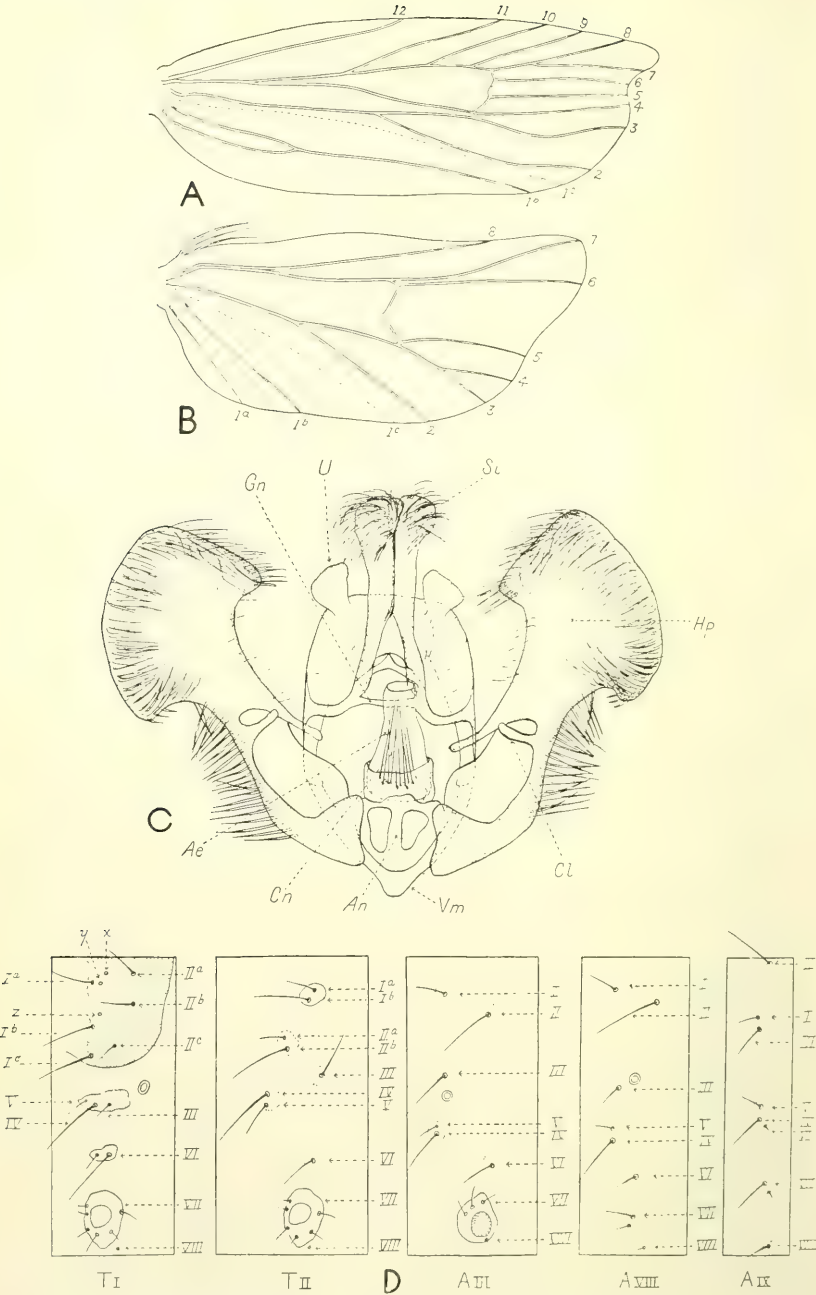


B

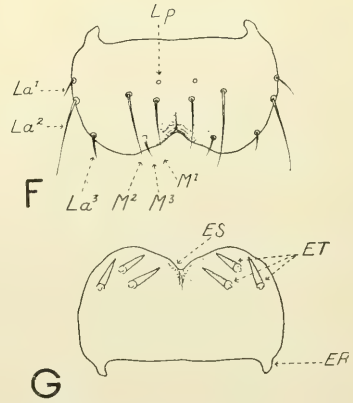
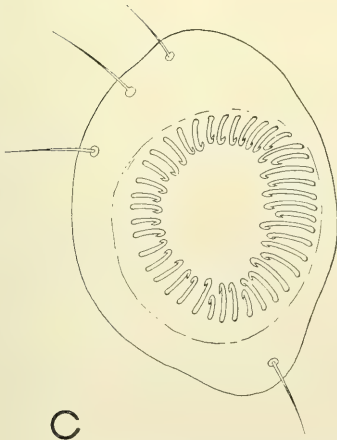
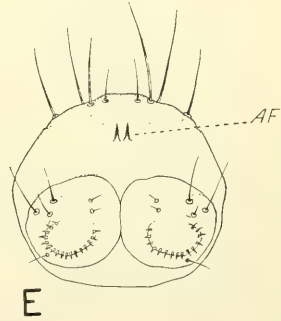
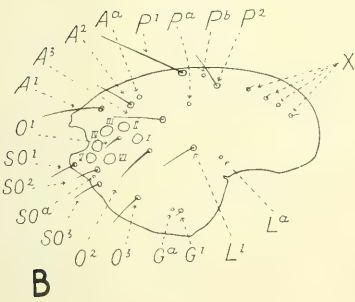
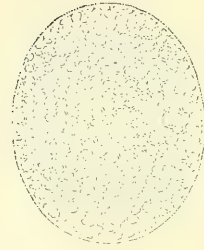
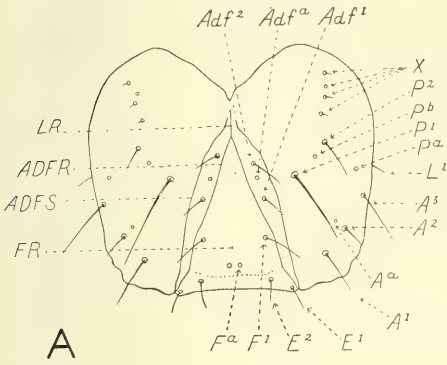


C

THE BLACKHEAD FIREWORM OF CRANBERRY.



THE BLACKHEAD FIREWORM OF CRANBERRY.



THE BLACKHEAD FIREWORM OF CRANBERRY.



BULLETIN No. 1033



Washington, D. C.

PROFESSIONAL PAPER

July 27, 1922

DIGESTIBILITY OF COD-LIVER, JAVA-ALMOND, TEA-SEED, AND WATERMELON-SEED OILS, DEER FAT, AND SOME BLENDED HYDROGENATED FATS.

By HARRY J. DEUEL, Jr., *formerly junior chemist*, and ARTHUR D. HOLMES, *formerly specialist in charge of nutrition experiments, Office of Home Economics, States Relations Service.*

CONTENTS.

	Page.		Page.
Purpose of investigations	1	Experiments—Continued.	
Experimental method	2	Watermelon-seed oil	7
Experiments	3	Deer fat	8
Cod-liver oil	3	Blended hydrogenated fats	9
Java-almond oil	5	Summary of results	15
Tea-seed oil	6		

PURPOSE OF INVESTIGATIONS.

An abundant supply of fat is of major importance in the consideration of nutrition, whether of the individual or the nation. Not only are fats wholesome, palatable, and most useful in cooking, but many also carry fat-soluble vitamin A.

Our older ideas regarding the indispensable rôle of fat in the diet must be somewhat modified if we accept the results of certain recent studies. Osborne and Mendel¹ conclude from experiments on rats that "if true fats are essential for nutrition during growth, the minimum necessary must be exceedingly small" and Drummond,² on the basis of similar studies, states that unless minute amounts of fat play as important a rôle in metabolism as do minute quantities of vitamins, it is reasonable to suggest that pure fats are dispensable constituents of the diet. Such findings, however, do not greatly lessen the importance of fats as a foodstuff. During the recent war, in the countries where the fat supply was far below normal, great discomfort and a serious lowering of health and of resistance to

¹ Jour. Biol. Chem., 45 (1920), No. 1, pp. 145–152.

² Jour. Physiol., 54 (1920), No. 4, p. XXX.

disease were common and physiologists generally believe that this was due, to some extent at least, to a lack of vitamin A. It should also be remembered that fats and oils represent the most concentrated source of body fuel, a fact that has an important bearing on the food transportation problem and on the cost of food to the consumer. An adequate national food policy therefore requires that an abundant fat supply be maintained during peace times as well as during war, and there is justification for the efforts made to find new sources of food fats and to make better use of those we now have.

For such reasons the Department of Agriculture has outlined a broad program for the study of edible fats, which includes investigation of the source of supply, methods of production and rectification, the relation of feed to fat production in farm animals, including the cost at which fat is produced at different ages, and the relation of this to the production of meat and dairy products. It also includes studies of the economical use of fat in cookery and its relation to the quality of the cooked product and of the thoroughness of digestion of fats and oils and the tolerance of the body to different kinds. These latter aspects of the problem have been for some years under investigation in the Office of Home Economics of the States Relations Service, cooperation with other bureaus being secured whenever this has seemed desirable.

The digestibility of 60 or more different fats and oils, some of animal and some of vegetable origin, has been tested in the Office of Home Economics. In a few cases, fish oil and avocado fat for instance, the fat was not extracted but was eaten as it occurs in these foods as ordinarily served. In most cases, however, the fat was rendered or otherwise freed from the tissue in which it occurs, and if necessary, further purified. These studies have been reported from time to time in publications of this department and in professional journals.³ This bulletin reports two groups of studies, one with a variety of fats and oils regarding which information was needed for special reasons, and one with blended hydrogenated fats such as are now in common use.

EXPERIMENTAL METHOD.

The method followed in these experiments was the same as that developed in the previous digestion experiments of this office. No method has yet been devised by which the proportion of nutrients actually digested from any one food material in a mixed diet can be directly measured, and all the methods now in use admit of at least

³ U. S. Dept. Agr. Buls. 310 (1915), 505 (1917), 507 (1917), 630 (1918), 687 (1918), 613 (1919), 781 (1919); Jour. Biol. Chem., 41 (1920), No. 2, pp. 227-235; Amer. Jour. Physiol., 54 (1921), No. 3, pp. 479-488

slight chances of error through the assumptions made regarding such factors as metabolic products and the digestibility of the nutrients in the basal diet. The procedure here adopted is believed to give as nearly correct results as any with which this office is familiar, and since it has been consistently followed in all the experiments in this laboratory, the results can be confidently said to show the relative digestibility of the various food materials thus studied. In comparing the results of studies conducted by one method with those by another, due allowance should be made for differences in procedure and calculation, and such allowance will frequently be found to lessen apparent conflicts or discrepancies in the findings which different investigators have obtained from experiments with similar materials.

The subjects in the present experiments were young men apparently in normal health, most of them students in a local university. They were familiar with this type of work, having served as subjects in previous experiments, and were entirely trustworthy. Each experiment was carried on for three days and included nine meals. The methods for separation of the feces, analyses, etc., were those usually followed.

In each experiment the special fat to be studied was incorporated in a cornstarch blanc-mange or pudding. This was eaten along with a basal ration which consisted of commercial wheat biscuit, oranges, and sugar and which supplied a very small amount of fat in comparison with that in the blanc-mange. Clear tea or coffee was included when desired.

The reports of the individual experiments are here presented in condensed form, but full data are on file in the Office of Home Economics.

EXPERIMENTS.

COD-LIVER OIL.

Though long and favorably known in medicine, especially in the treatment of tuberculosis and other wasting diseases, cod-liver oil has had no general use for food purposes. It has, however, entered into the diet to some extent, both the cod livers and the oil finding some use as food. Dr. Vivia Appleton, who has studied diet in Labrador, has stated in personal communications that cod livers are there considered a delicacy and she believes them to be a valuable source of vitamin A. Fishermen from points north of Boston are said to take the crude oil from cod livers and eat it spread on bread. The shortage of fat and particularly milk fat, ordinarily the most important source of vitamin A in child feeding, led Chick and Dalyell⁴ to use

⁴ Brit. Med. Jour. No. 3109 (1920), pp. 151-154.

cod-liver oil extensively as a food fat in the relief work with children in Vienna after the war. The success of this makes it clear that cod-liver oil can be relied on for such a purpose whenever circumstances make this desirable.

Many experimental studies of cod-liver oil have been reported in medical literature. Some of the most interesting are those dealing with its iodine content, which Andr  s, quoted by Lewkowitsch, reports as 0.02 for pale oil and 0.03 per cent ⁵ for yellow oil, and to which its therapeutic value has been attributed by some.

Osborne and Mendel ⁶ first noted the remarkable potency of cod-liver oil in vitamin A. More recently Zilva and Miura have shown by new quantitative methods that crude cod-liver oil is in some cases two hundred and fifty times as potent as butter fat and refined cod-liver oil many times superior to butter in this respect.⁷ This has naturally aroused much interest in the relation between its vitamin content and its therapeutic value. Such investigations, together with its successful use in the treatment of malnutrition in Vienna, can hardly fail to bring about a more general use of cod-liver oil as food fat.

It is interesting to note that cod-liver oil has been studied in animal feeding, specifically its effect on milk production when used as a supplement to other fat in the ration of dairy cows. Hart, Steenbock, and Hoppert report ⁸ that the daily addition of from 5 to 10 cubic centimeters of cod-liver oil to the diet of dry and milking goats consistently changed negative calcium balances to positive, showing that some factor affecting calcium assimilation is present in cod-liver oil.

The digestibility of cod-liver oil by man has been studied by Wells,⁹ who fed 100 grams per day to human subjects and found that it was well assimilated. No significant difference was noted between the emulsified and the unemulsified oil, the coefficients of digestibility being respectively 96 and 97 per cent. Judging by the results obtained, the cod-liver oil slightly increased the thoroughness of digestion of the other fats present in the experimental ration.

In the experiments made in this laboratory no difficulty was experienced in feeding the cod-liver oil, the flavor being well masked by the caramel and vanilla extract used in the cornstarch pudding which served as a vehicle for the fat. The results of four experiments are summarized in Table 1.

⁵ Chemical Technology and Analysis of Oil, Fats, and Waxes. 1909, 4 ed., vol. 2, p. 361.

⁶ Jour. Biol. Chem., 17 (1914), No. 3, pp. 401-408.

⁷ Lancet [London], 200 (1921), No. 5085, p. 323.

⁸ Jour. Biol. Chem., 48 (1921), pp. 33-50.

⁹ Brit. Med. Jour. No. 2181 (1902), pp. 1222-1224.

TABLE 1.—*Summary of digestion experiments with cod-liver oil in a simple mixed diet.*

Experiment No.	Subject.	Digestibility of entire ration.				Digestibility of cod-liver oil alone.
		Protein.	Fat.	Carbohydrate.	Ash.	
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
1143.....	C. J. G.....	64.5	91.3	96.4	62.0	97.2
1144.....	H. L. G.....	65.6	96.5	96.6	70.4	100.0
1145.....	E. L. M.....	12.8	88.9	95.9	32.5	95.2
1146.....	J. F. S.....	59.2	93.8	96.6	47.5	98.4
Average.....	.....	50.5	92.6	96.4	53.1	97.7

The food eaten per man per day provided on an average 16 grams of protein, 47 grams of fat, and 310 grams of carbohydrate, and its fuel value averaged 1,740 calories. The maximum amount of cod-liver oil consumed by any subject was 53 grams per day. The coefficient of digestibility was high in every case, and the average figure, 97.7 per cent, indicates a very complete utilization. Except that all the subjects were somewhat constipated, no physiological disturbance was noted.

In thoroughness of digestion, cod-liver oil agrees closely with the majority of fats and oils that have a melting point at or below body temperature.

JAVA-ALMOND OIL.

The digestibility of this oil is of interest not only because the nut is valued highly in Java, but also because the finely ground kernels mixed with water to a kind of emulsion and added to milk find there a special use in infant feeding with, it is believed, good results.

The Java almonds (*Canarium commune*) needed for this experiment were obtained from Java by the Office of Foreign Seed and Plant Introduction, Bureau of Plant Industry. The nut resembles somewhat a small-sized pecan in shape, and the kernels are much like a small almond in appearance and have a very agreeable flavor.

In the present work a small-sized laboratory oil press was used to express the oil, which was of clear yellow color and bland in flavor.

The supply available was sufficient for only two tests. The results are summarized in Table 2.

TABLE 2.—*Summary of digestion experiments with Java-almond oil in a simple mixed diet.*

Experiment No.	Subject.	Digestibility of entire ration.				Digestibility of Java-almond oil alone.
		Protein.	Fat.	Carbohydrate.	Ash.	
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
1154.....	H. L. G.....	52.2	95.5	96.2	66.3	99.4
1155.....	E. L. M.....	30.5	89.0	96.5	36.6	94.5
Average.....	.....	41.4	92.2	96.4	51.4	97.0

The food eaten per man per day provided on an average 15 grams of protein, 61 grams of fat, and 311 grams of carbohydrate and its fuel value averaged 1,860 calories. The average coefficient of digestibility of the Java-almond oil, which made up over 98 per cent of the total fat of the diet, was 97 per cent. So far as may be judged by the continued good condition of the subjects, the palatability of the oil, and its high digestibility, there is good reason to conclude that it compares favorably with other nut oils used in this laboratory.

TEA-SEED OIL.

The best grades of tea-seed oil are used to some extent for food purposes in China and have been found as an adulterant of cabbage oil. The Chinese use poorer grades for burning and for soap making. That used in the tests here reported was a commercial product of a pale yellow color and bland flavor.

The fitness of this by-product oil for food has been questioned on the ground that, as saponin has been found in it, it may be harmful. Hooper¹⁰ reports 9 per cent saponin in tea seed and states that some is always dissolved by the oil. Weil¹¹ states that oil made by extraction contains no saponin. The oil used in the present experiments was examined for saponin in the Pharmacological Laboratory, Bureau of Chemistry, with negative results.

The experiment was begun with three subjects, who ate some 40 to 50 grams of the oil per man per day. Owing to the accidental loss of some of the feces in the case of two subjects, complete data are available from only one person. The available results are summarized in Table 3.

TABLE 3.—*Data of digestion experiments with tea-seed oil in a simple mixed diet.*

Experiment No.	Subject.	Digestibility of entire ration.				Digestibility of tea-seed oil alone.
		Protein.	Fat.	Carbo-hydrate.	Ash.	
1004.....	J. F. C.....	Per cent. 47.2	Per cent. 88.2	Per cent. 98.4	Per cent. 42.1	Per cent. 91.2

The daily food of the subject for whom the experimental data are complete, provided on an average 9 grams of protein, 50 grams of fat, and 204 grams of carbohydrate, and its fuel value averaged 1,300 calories. The average amount of tea-seed oil eaten daily was 49 grams. The subject remained in his usual good health and suffered no noticeable physiological disturbances. This was equally

¹⁰ Pharm. Jour. and Trans. [London], 3, ser., 25 (1895), No. 1282, p. 605.

¹¹ Arch. Pharm., 239 (1901), No. 5, pp. 365.

true for the two other subjects, both of whom ate the experimental diet for three days. The coefficient of digestibility, 91.2 per cent, obtained in the one complete test is somewhat lower than is usual with oils liquid at body temperature, but the data are too limited to be taken as conclusive. All that can fairly be said on the basis of the work here reported is that tea-seed oil appeared to be well tolerated and over 90 per cent digested.

WATERMELON-SEED OIL.

Watermelon-seed oil is at present made only for experimental purposes, but its possible economic and commercial importance is suggested by the fact that another cucurbit fat previously studied, pumpkin-seed oil, is well known as a food product. It was therefore included in the present series of tests.

Watermelon-seed oil is easily expressed from the seed which, according to Lewkowitsch¹² will yield 40.8 per cent. It is light brown in color and pleasing in flavor. That used in the experiments here reported was obtained through the courtesy of F. Rabak, of the Bureau of Plant Industry. The quantity available was limited and so the amount supplied per day to the subjects was less than usual in such experiments.

Tests were made with three subjects. The results are summarized in Table 4.

TABLE 4.—*Summary of digestion experiments with watermelon-seed oil in a simple mixed diet.*

Experiment No.	Subject.	Digestibility of entire ration.				Digestibility of watermelon-seed oil alone.
		Protein.	Fat.	Carbohydrate.	Ash.	
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
999.....	J. F. C.....	65.9	89.4	98.6	53.7	92.5
1001.....	G. S. M.....	41.6	88.5	97.0	29.7	93.9
1002.....	W. O'C.....	62.2	94.2	98.0	27.8	97.9
Average.....		56.9	90.7	97.9	37.1	94.8

The total food consumed per man per day supplied on an average 9 grams of protein, 32 grams of fat of which nearly 30 grams were watermelon-seed oil, and 215 grams of carbohydrate, and its fuel value averaged 1,190 calories. No special physiological effects were noted and the coefficient of digestibility, 94.8 per cent, was relatively high. In general it can be said that watermelon-seed oil resembles the two other cucurbit-seed oils previously studied, cantaloup and pumpkin-seed oils, both of which had a coefficient of diges-

¹² Chemical Technology and Analysis of Oils, Fats, and Waxes. 1909, 4. ed., vol. 2, p. 126.

tibility of 98.2 per cent.¹³ Like these oils it was well tolerated and so far as can be judged would be useful for food purposes if available commercially.

DEER FAT.

While the fat of the various species of deer is not a commercial product in the United States, in some localities it is a constituent of the human dietary, especially during the open season. In this connection it is interesting to recall that in Alaska the carcass as well as the milk of the reindeer is used for food and reindeer fat forms no inconsiderable part of the diet. The importance of caribou fat in the diet of natives and others in the Arctic region is well brought out in accounts of such travelers and explorers as Stefánsson.¹⁴

For the experiments reported below two shipments of fat from white-tailed Virginia deer were obtained through the courtesy of John B. Burnham, president of the American Game Protective and Propagation Association. The crude deer fat was taken from a number of animals shot in New England and New York during late fall and early winter. No information was available concerning the part of the body from which the fat was taken, but in general appearance the crude fat resembled somewhat the "leaf" or kidney fat of mutton. The various lots received were rendered together and the product is believed to be typical of deer fat. Its melting point was found to be 51.4° C. This is not unlike the figures quoted by Lewkowitsch,¹⁵ which show that the melting points of fat from different species of deer vary between 49° C. and 54° C.

Only three experiments were made as the available supply of deer fat was limited. The results are summarized in Table 5.

TABLE 5.—*Summary of digestion experiments with deer fat in a simple mixed diet.*

Experiment No.	Subject.	Digestibility of entire ration.				Digestibility of deer fat alone.
		Protein.	Fat.	Carbohydrate.	Ash.	
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
750.....	P. K.....	59.5	71.5	95.5	47.0	78.0
752.....	J. C. M.....	65.3	73.9	95.8	45.4	81.2
753.....	A. A. R.....	31.9	75.4	95.6	41.0	85.8
Average.....	.....	52.2	73.6	96.0	44.5	81.7

The food eaten per man per day provided on an average 25 grams of protein, 46 grams of fat, and 311 grams of carbohydrate, and its fuel value averaged 1,760 calories. The diet as a whole was well

¹³ U. S. Dept. Agr. Bul. 781 (1919).

¹⁴ *My Life with the Eskimo*. 1913.

¹⁵ *Chemical Technology and Analysis of Oils, Fats, and Waxes*. 1909, 4. ed., vol. 2, pp. 723, 724.

assimilated, no physiological disturbance was noted, and the deer fat, though its melting point is rather high as compared with common food fats, did not lower the digestibility of the other ingredients of the diet.

The average figure reported for digestibility of deer fat, 81.7 per cent, is considerably lower than that found in most of the experiments made in this laboratory with fats. The only exceptions were hydrogenated peanut oil which had a melting point of 52.4° C. and showed practically the same coefficient of digestibility,¹⁶ 79 per cent, and oleo stearin which was 80.1 per cent digested.¹⁷

Though the amount of deer fat eaten per man per day is small compared with other fats previously studied in this laboratory, it constituted the major portion of the total fat eaten in all three tests and there seems no reason to doubt the accuracy of the results.

The average results of the experiments with cod-liver, Java-almond, tea-seed, and watermelon-seed oils and deer fats are summarized in Table 6.

TABLE 6.—*Summary of results of digestion experiments with certain miscellaneous oils and fat in a mixed diet.*

Material tested.	Digestibility of entire ration.				Digestibility of oil or fat alone.
	Protein.	Fat.	Carbohydrate.	Ash.	
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Cod-liver oil.....	50.5	92.6	96.4	53.1	97.7
Java-almond oil.....	41.4	92.2	96.4	51.4	97.0
Tea-seed oil.....	47.2	88.2	98.4	42.1	91.2
Watermelon-seed oil.....	56.9	90.7	97.9	37.1	94.8
Deer fat.....	52.2	73.6	96.0	44.5	81.7

BLENDING HYDROGENATED FATS.

During the last 10 or 15 years the hydrogenation process has come prominently into use for the preparation of solid fats from liquid oils. This procedure, although limited in general use to those oils which have a fairly large amount of unsaturated fatty acids, finds application in the hardening of a number of vegetable and animal oils that are produced in quantity.

There are two general methods for the preparation of hydrogenated fats. In one, all the oil is subjected to the hydrogenation process until a fat of the desired melting point is obtained. In the other, part of the oil is hydrogenated until a fat with a very high melting point is obtained, which is then mixed with a sufficient amount of the untreated oil to give a fat of the desired melting point. In the discus-

¹⁶ Amer. Jour. Physiol., 54 (1921), No. 3, pp. 479-488.

¹⁷ U. S. Dept. Agr. Bul. 613 (1919).

sion which follows such fats are designated "blended fats" in contrast to the "hydrogenated oils" made by hydrogenating the entire quantity of oil.

It has been claimed that this blended fat is inferior in keeping qualities to that produced by hydrogenation alone.¹⁸ The blending method is, however, generally given preference because of the larger production possible with a given equipment. Moreover, the blended fat may supply vitamins, if any were present in the oil that is blended with the hardened fat.

A previous paper from this laboratory reported a series of 44 experiments on corn, cottonseed, and peanut oils hydrogenated to different degrees of hardness.¹⁹ It was found that with the exception of hydrogenated peanut oil melting at 52.4° C., which was 79 per cent digested, and corn oil melting at 50° C., which was 88.5 per cent digested, the hydrogenated oils studied had coefficients of digestibility of 92 per cent or higher. No one of them caused any observed digestive disturbance nor was a decrease in the digestibility of the experimental diet as a whole noted in any case. In general, the results showed that as the melting point of the hydrogenated oil increased the digestibility decreased, the decrease being much more marked with those melting at over 46° C.

To determine whether or not blended fats have the same digestibility as hydrogenated oils made from the same kinds of oils and having approximately the same melting point, such blended fats were used in the experiments here reported. They were made for the purpose from the same lots of corn, cottonseed, and peanut oils used in the earlier experiments with hydrogenated oils.²⁰

The hard fats used in the preparation of the majority of the blended fats were prepared in the laboratory of Carleton Ellis by one of the authors (H. J. D.) of this bulletin assisted by J. R. Kuhn. The oils were completely saturated with hydrogen at 180° C. and had a melting point, in every case, of approximately 60° C. In the case of the two blended cottonseed fats, with melting points of 41.3° C. and 50° C., cotton stearin obtained from the Bureau of Animal Industry was mixed with a good grade of commercial edible cottonseed oil obtained from the Bureau of Chemistry. The melting points, iodine numbers, and proportions of hardened and untreated oil in the fats used are shown in Table 10, page 13.

These blended fats were white, solid or practically so at room temperature, and without any characteristic odor or taste. When melted, their color was yellow, resembling that of tallow. If allowed

¹⁸ Rogers, A. *Manual of Industrial Chemistry*. 1915, 2. ed., p. 601.

¹⁹ Holmes, A. D., and Deuel, H. J., jr., *Amer. Jour. Physiol.*, 54 (1921), No. 3, pp. 479-488.

²⁰ *Amer. Jour Physiol.*, 54 (1921), No. 3, pp. 479-488.

to cool slowly, the stearin separated out leaving a liquid layer on top of it. When cooled quickly with continued stirring, a homogeneous, white compound was obtained which resembled lard.

Blended corn fats.—Ten digestion experiments were conducted with blended corn fat, four with fat melting at 39° C. and three each with fats melting at 49° C. and 54° C. The results are summarized in Table 7.

TABLE 7.—*Summary of digestion experiments with blended corn fats in a simple mixed diet.*

Experiment No.	Melting point of fat.	Subject.	Digestibility of entire ration.			Digestibility of blended corn fat alone.
			Protein.	Fat.	Carbohydrate.	
	° C.		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
1113.....	39	P. C.....	53.3	94.4	96.7	97.2
1115.....	39	H. L. G.....	67.1	94.9	97.0	97.4
1116.....	39	E. L. M.....	13.0	90.5	96.8	94.4
1117.....	39	J. F. S.....	54.9	88.5	96.2	91.9
Average.....			47.8	92.1	96.7	95.2
1128.....	49	H. L. G.....	67.4	91.7	95.6	94.9
1129.....	49	E. L. M.....	59.9	92.4	98.0	94.7
1130.....	49	J. F. S.....	58.4	87.0	96.5	90.2
Average.....			61.9	90.4	96.7	93.3
1132.....	54	H. L. G.....	65.3	89.7	96.8	93.0
1133.....	54	E. L. M.....	29.1	83.5	96.1	88.5
1134.....	54	J. F. S.....	64.2	90.1	96.8	92.9
Average.....			52.9	87.8	96.6	91.5

The average amount of blended corn fat eaten per man per day was 102.9 grams for the fat melting at 39° C., 105.4 grams for the fat melting at 49° C., and 92.5 grams for the fat melting at 54° C. The maximum amounts eaten per day were 121.2 grams of fat melting at 39° C. in experiment No. 1117, 126.2 grams of fat melting at 49° C. in experiment No. 1130, and 103.7 grams of fat melting at 54° C. in experiment No. 1134. The digestibility of the blended corn fat was on an average 95.2 per cent for the 39° fat, 93.3 per cent for the 49° fat, and 91.5 per cent for the 54° fat. The subjects experienced no physiological disturbances during the three-day experimental periods.

The blended fat melting at 54° was somewhat better digested than the hydrogenated corn oil melting at 50° used in the earlier experiments, although the blended fat was eaten on an average in twice as large amounts as the hydrogenated fat.

Blended cottonseed fats.—Thirteen experiments are reported with blended cottonseed fat, two each with the fat melting at 41.3° C., 45.8° C., and 48.1° C., three with the fat melting at 50° C., and four with the fat melting at 47.8° C. The results are summarized in Table 8.

TABLE 8.—*Summary of digestion experiments with blended cottonseed fats in a simple mixed diet.*

Experiment No.	Melting point of fat.	Subject.	Digestibility of entire ration.			Digestibility of blended cottonseed fat alone.
			Protein.	Fat.	Carbohydrate.	
	° C.		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
479.....	41.3	H. R. G.....	57.7	92.8	94.8	97.8
481.....	41.3	P. K.....	76.8	91.9	96.8	95.4
Average.....			67.2	92.4	95.8	96.6
1149.....	45.8	E. L. M.....	61.1	90.5	97.5	94.6
1150.....	45.8	J. F. S.....	53.4	93.8	96.7	98.2
Average.....			58.8	92.2	97.1	96.4
1135.....	47.8	C. J. G.....	66.6	85.4	96.5	90.0
1136.....	47.8	H. L. G.....	58.8	92.0	96.0	95.3
1137.....	47.8	E. L. M.....	49.3	91.2	96.7	94.5
1138.....	47.8	J. F. S.....	75.4	94.0	97.9	96.1
Average.....			62.5	90.7	96.8	94.2
1152.....	48.1	E. L. M.....	61.8	90.2	97.5	95.7
1153.....	48.1	J. F. S.....	40.0	89.5	95.8	95.0
Average.....			50.9	89.8	96.6	94.4
421.....	50	H. R. G.....	55.7	76.3	96.7	82.6
423.....	50	R. L. S.....	64.8	85.6	97.5	89.9
424.....	50	O. E. S.....	61.5	84.1	97.5	88.4
Average.....			60.7	82.0	97.2	87.0

The subjects ate on an average per man per day 62.3 grams of the fat melting at 41.3° C., 52.6 grams of the fat melting at 45.8° C., 76.3 grams of the fat melting at 47.8° C., 49.4 grams of the fat melting at 48.1° C., and 56.9 grams of the fat melting at 50° C. The maximum eaten per day was 63.3 grams of the 41.3° C. fat, 52.8 grams of the 45.8° C. fat, 98.1 grams of the 47.8° C. fat, 53.3 grams of the 48.1° C. fat, and 62.7 grams of the 50° C. fat. The average coefficients of digestibility found were 96.6 per cent for the 41.3° C. fat, 96.4 per cent for the 45.8° C. fat, 94.2 per cent for the 47.8° C. fat, 94.4 per cent for the 48.1° C. fat, and 87 per cent for the 50° C. fat. The subjects remained in normal health except for the experiments with fat melting at 50° C. In the reports of their condition in this case the subjects mentioned a feeling of nausea and headache. Such conditions were not noted in the other experiments with hydrogenated fats of high melting point and may not be directly ascribable to the fat ingested. Similar effects had been noted in earlier experiments in which cocoa fat²¹ and cupuassú fat²² were eaten in large quantities.

Blended peanut fats.—Thirteen experiments were conducted with blended peanut fat, five with fat melting at 43° C. and four each with fats melting at 43.2° C. and 51.1° C. The results are summarized in Table 9.

²¹ U. S. Dept. Agr. Bul. 505 (1917).

²² Jour. Biol. Chem., 41 (1920), No. 2, pp. 227-235. Cupuassú fat is expressed from the seed of the fruit of the cupuassu tree (*Theobroma grandiflora* Schum).

TABLE 9.—*Summary of digestion experiments with blended peanut fats in a simple mixed diet.*

Experiment No.	Melting point of fat.	Subject.	Digestibility of entire ration.			Digestibility of blended peanut fat alone.
			Protein.	Fat.	Carbohy- drate.	
	° C.		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
1088.....	43	P. C.....	63.3	94.2	96.2	98.4
1089.....	43	W. V. D.....	71.0	91.5	98.3	94.5
1090.....	43	H. L. G.....	53.4	91.5	96.1	96.0
1091.....	43	E. L. M.....	61.5	93.0	97.1	96.4
1092.....	43	J. F. S.....	63.4	93.1	96.3	97.6
Average.....			62.5	92.7	96.8	96.6
1093.....	43.2	P. C.....	78.0	95.7	97.2	98.4
1094.....	43.2	W. V. D.....	76.7	97.0	98.7	99.3
1095.....	43.2	H. L. G.....	66.9	93.4	96.6	96.7
1097.....	43.2	J. F. S.....	52.4	91.3	96.8	95.2
Average.....			68.5	94.4	97.3	97.4
1098.....	51.1	P. C.....	58.4	91.8	97.5	94.3
1100.....	51.1	H. L. G.....	61.5	89.4	97.1	92.8
1101.....	51.1	E. L. M.....	56.0	87.2	97.3	90.8
1102.....	51.1	J. F. S.....	75.8	90.8	97.7	93.2
Average.....			62.9	89.8	97.4	92.8

The subjects ate on an average per man per day 73.8 grams of the fat melting at 43° C., 79.7 grams of the fat melting at 43.2° C., and 90.3 grams of the fat melting at 51.1° C. The maximum amount of blended peanut fat eaten per man per day was 78.4 grams of the 43° C. fat, 100.1 grams of the 43.2° C. fat, and 109.6 grams of the 51.1° C. fat.

The average coefficients of digestibility were 96.6 per cent for the 43° C. fat, 97.4 per cent for the 43.2° C. fat, and 92.8 per cent for the 51.1° C. fat. The subjects remained in apparently normal health and suffered no physiological disturbances.

Discussion.—A summary of the results obtained from these experiments with blended fats of different melting points prepared out of corn, cottonseed, and peanut oil is given in Table 10.

TABLE 10.—*Summary of digestion experiments with blended vegetable fats in a simple mixed diet.*

Number of experiments conducted.	Kind of fat.	Melting point of fat.	Iodin number.	Fats in blend.		Digestibility of blended fat alone.
				Hardened fat.	Untreated oil.	
		° C.		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
4	Corn.....	39	89.7	9.1	90.9	95.2
3	do.....	49	84.8	25.0	75.0	93.3
3	do.....	54	85.8	30.8	69.2	91.5
2	Cottonseed.....	41.3				96.6
2	do.....	45.8	84.8	12.5	87.5	96.4
4	do.....	47.8	82.4	18.8	81.2	94.2
2	do.....	48.1	80.0	23.5	76.5	94.4
3	do.....	50.0		22.1	77.9	87.0
5	Peanut.....	43.0	80.9	6.2	93.8	96.6
4	do.....	43.2	82.4	9.1	90.9	97.4
4	do.....	51.1	75.5	33.3	66.7	92.8

The fats studied showed coefficients of digestibility ranging from 91.5 to 97.4 per cent, except in blended cottonseed fat melting at 50° C., which gave a coefficient of digestibility of 57 per cent. It is interesting to note that the blended fat with the highest melting point, namely, corn fat melting at 54° C., was 91.5 per cent digested, while straight hydrogenated peanut fat with a melting point of 52.4° C. was found to be only 79 per cent digested.

A comparison between Table 10 and Table 11, adapted from the report²³ of earlier work with hydrogenated oils of the same origin as those used in blended form, gives an idea of the relative effect of the two methods of preparation upon digestibility.

TABLE 11.—*Summary of digestion experiments with hydrogenated vegetable oils in a simple diet.*

Number of experiments conducted.	Kind of fat.	Melting point of fat.	Iodin number.	Digestibility of entire ration.			Digestibility of hydrogenated vegetable oil alone.
				Protein.	Fat.	Carbohydrate.	
		° C.		Per cent.	Per cent.	Per cent.	Per cent.
5	Cottonseed	35	89.6	69.2	93.6	96.9	96.8
1	do.	38.6	-----	69.5	92.7	97.3	95.5
3	do.	46	72.8	71.7	92.7	97.6	94.9
5	Peanut	37	81.3	69.1	95.0	96.9	98.1
3	do.	39	-----	74.0	93.3	97.6	95.9
5	do.	43	78.8	73.8	93.5	96.8	96.5
4	do.	50	58.5	68.6	88.1	97.6	92.0
3	do.	52.4	-----	55.9	73.8	97.2	79.0
5	Corn	33	89.0	72.0	91.7	97.4	94.7
5	do.	43	74.9	76.3	91.8	97.0	95.4
5	do.	50	55.4	69.6	83.2	97.3	88.5

The blended fats seem to be, as a rule, slightly better utilized than the straight hydrogenated oils melting at the same temperature.

While no definite data are available regarding the cause of higher digestibility for blended fats, it is not without interest to suggest, as was done in an earlier paper, that in the process of digestion saponification may take place only on the exterior of the particles of hardened fat (i. e., for those melting at temperatures considerably above that of the human body), which decrease in size as the process of digestion continues. If surface area be thus a factor, then the rate of digestion and possibly the extent of digestion of a hydrogenated fat having a high melting point is governed to some extent by the size of the particles of hydrogenated fat ingested. If this hypothesis be tenable, it follows that particles of blended fat which are honey-combed with veins of a low melting fat would, after they had come to the temperature of the body, present greater surface area than particles of straight hydrogenated oil, which present only an exterior surface to the action of the digestive juices.

²³ Amer. Jour. Physiol., 54 (1921), No. 3, pp. 479-488.

The blended fats were eaten in relatively large quantities and caused no apparent physiological disturbances. While the number of experiments here reported is small, it is believed the data are sufficient to permit the conclusion that the digestibility of these blended fats compares favorably with that of the natural fats of corresponding melting points.

SUMMARY OF RESULTS.

For purposes of general comparison the average results of the preceding experiments on the digestibility of oils and fats are summarized in Table 12.

TABLE 12.—Average digestibility of oils and fats in a mixed diet.

Kind of oil or fat.	Melting point.	Digestibility.	Kind of oil or fat.	Melting point.	Digestibility.
	° C.	Per cent.		° C.	Per cent
Cod-liver oil.....		97.7	Blended hydrogenated fats:		
Java-almond oil.....		97.0	Cottonseed fat.....	41.3	96.6
Tea-seed oil.....		91.2	Do.....	45.8	96.4
Watermelon-seed oil.....		94.8	Do.....	47.8	94.2
Deer fat.....	51.4	81.7	Do.....	48.1	94.4
Blended hydrogenated fats:			Do.....	50.0	87.0
Corn fat.....	39.0	95.2	Peanut fat.....	43.0	96.6
Do.....	49.0	93.3	Do.....	43.2	97.4
Do.....	54.0	91.5	Do.....	51.1	92.8

In general the results obtained in these studies agree with those reported in the other investigations made by this office on the digestibility of fats and oils.

ADDITIONAL COPIES

OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.

AT

5 CENTS PER COPY



UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1034



Contribution from the Office of Farm Management
and Farm Economics

G. W. FORSTER, Acting Chief

Washington, D. C.

PROFESSIONAL PAPER

June 28, 1922

FARM MANAGEMENT AND FARM ORGANIZATION IN
SUMTER COUNTY, GA.

AN ANALYSIS OF THE BUSINESS OF 534 FARMS IN 1913, AND 550
FARMS IN 1918.

By H. W. HAWTHORNE, *Assistant Farm Economist*; H. M. DIXON, *Associate
Farm Economist*; and FRANK MONTGOMERY, *Assistant Farm Economist*.

CONTENTS.

	Page.		Page.
Introduction.....	1	Farm organization and business	
Summary of results.....	3	analysis of farms—Continued.	
Area studied.....	5	Farm earnings.....	31
Utilization of the land.....	7	Family farms.....	38
Farm organization and business		Choice of enterprises.....	43
analysis of farms.....	8	Diversity.....	46
Size of farms.....	10	Factors affecting successful opera-	
Crops grown and yields.....	11	tion of these farms.....	50
Receipts.....	21	Bearing of farm organization on	
Expenses.....	25	cost of producing cotton.....	58
Capital.....	28	Appendix.....	72

INTRODUCTION.

THIS BULLETIN presents¹ data regarding organization, production, expenses, and returns of farms operated by owners and tenants (renters), both white and colored.

The studies were made to determine the significant factors that make for success or failure in the management of representative farms in southern Georgia. They bring out the bearing of such factors as size of business and yield per acre upon profits and the cost of producing cotton, and are believed to be of special significance in that the repetition of the farm business analysis has made possible

¹ The method used in this business analysis study is described in Farmer's Bulletin 1139.

comparisons that show the changes that have taken place in organization and management of the farms during the five-year period.²

The conclusions reached concerning the organization and farming practice best suited to the conditions of this region will undoubtedly apply to a much wider area than that for which they are directly drawn, in short, to practically all localities where similar conditions prevail.

The first year of the study, 1913, was a representative prewar year. The farms included reported an average of 38 bales of cotton per farm, 258 pounds of lint per acre, selling at 12.2 cents per pound. In 1918, although the farms were slightly larger than in 1913, they produced an average of 26 bales of cotton per farm, 234 pounds of lint per acre, selling at 29.2 cents per pound.

Between 1913 and 1918, Sumter County farmers had to face conditions that made desirable important changes in the organization of farms. In 1915 the boll-weevil appeared in the county, and though it did not work such disaster as in many other sections, the farmers were alert to the seriousness of the situation, and having the benefit of the experience of farmers in areas previously infested, they immediately began changes in their farm organization and operation to meet the new condition.

They could do this the more readily because there had been changes in prices, and an increasing demand for farm products other than cotton had arisen. A meat-packing industry was being developed, increased facilities for preparing the peanut and its products for the market were being installed, and increased or improved facilities were being provided for the preparation and marketing of many other products.

The data for 1918, as compared with those for 1913, show the extent to which changes had taken place in the area since the earlier survey. While the acreage in cotton was decreased, the total acreage in crops was maintained by planting more corn, wheat, and peanuts. This represents a better farm practice, making a more even distribution of labor demands throughout the year. Furthermore, the rais-

² A report of the business analysis of the 534 farms for 1913 is found in Department Bulletin 492, "An Economic Study of Farming in Sumter County, Georgia." The 1913 material reworked to accord with present-day methods is embodied in this report. The data for 1918 were obtained in cooperation with the Georgia State College of Agriculture.

Acknowledgment is due to the farmers of Sumter County, who cooperated in obtaining the data presented herein; to Messrs. S. H. Starr, De F. Hungerford and G. V. Cunningham, of Georgia Agricultural College, and Messrs. C. L. Goodrich, J. S. Ball, A. P. Brodell, M. R. Cooper, M. A. Crosby, W. C. Funk, E. S. Haskell, H. B. McClure, Bruce McKinley, A. D. McNair, M. B. Oates, F. H. Shelledy, F. D. Stevens, and R. S. Washburn, of the Office of Farm Management and Farm Economics, who assisted either one or both years in obtaining the data; and to Dr. G. F. Warren, of Cornell University, and Prof. J. R. Fain, of Georgia Agricultural College.

Acknowledgement is also due Miss Mabel G. Darcey and staff of clerical assistants for compilation of these data.

ing of more legumes, and the practice of following a definite rotation became well-established upon many of the farms. More cowpeas, velvet beans, and peanuts were planted with corn, and more cowpeas followed the small grain crops. The production of hogs and peanuts for market was substantially increased.

By carrying the business analysis of farms operated by white owners and tenants and by colored owners and tenants separately in the tables that follow, an opportunity for comparisons that serve to throw light on certain important economic problems of southern agriculture was presented.

SUMMARY OF RESULTS.

White owners operated about half of both the 534 farms studied in 1913 and the 550 studied in 1918, these farms representing more than two-thirds of the total crop acreage reported, and producing almost three-fourths of the cotton. Colored tenants were the most numerous of the other classes, operating one-third of all farms, handling one-sixth of the crop acreage, and producing almost one-sixth of the cotton. The farms ranged in size from less than 50 acres to over 1,000, and yields of lint cotton from less than 100 pounds to over 500 per acre.

Outstanding changes in farm organization disclosed as having taken place between 1913 and 1918 (white-owner farms) were as follows:

Cotton acreage per farm decreased one-third—

1913 ████████████████████ (57 per cent crop acreage.)

1918 ████████████████████ (37 per cent.)

Corn acreage increased till it about equaled cotton acreage—

1913 ████████████████████ (28 per cent of crop acreage.)

1918 ████████████████████ (37 per cent.)

Wheat acreage increased—

1913, almost none.

1918, wheat grown on about two-thirds of farms.

Peanut acreage increased—

1913 ████████████████████ (2 per cent of crop acreage.)

1918 ████████████████████ (10 per cent.)

Applications of fertilizer decreased 37 per cent—

1913, 390 pounds per acre.

1918, 244 pounds per acre.

Introduction of the velvet bean (usually interplanted with corn).

Increase in live-stock production (particularly hogs).

Increase in acreage of legumes (velvet beans, cowpeas, and peanuts).

Wider utilization of land for second and interplanted crops.

Tendency of share-cropper labor to supplant wage labor.

These changes occurred to a greater extent on farms operated by white owners than on those of other classes of farmers. The colored operators tend to stick closer to cotton than do the white operators.

Farm earnings were much higher in 1918 than in 1913, apparently owing altogether to higher prices of farm products, increased production being a negligible factor.

Average farm income —

	1913.	1918.
White owners----	\$1,665	\$3,711
White tenants----	564	1,353
Colored owners--	805	1,778
Colored tenants--	323	843

Average labor income—

	1913.	1918.
White owners----	\$474	\$1,813
White tenants----	505	1,232
Colored owners--	263	1,058
Colored tenants--	290	768

Average per cent return on capital—

	1913.	1918.
White owners-----	7	11.3
Colored owners-----	7	13.7
Landlords of white tenants-----	6.4	9.4
Landlords of colored tenants-----	8.6	14.1

Estimated value of family living from farm (food, fuel, shelter), 1918. (No data for 1913)—

White owners-----	\$716
White tenants-----	560
Colored owners-----	597
Colored tenants-----	434

Between 1913 and 1918 the average estimated value of real estate on the white-owner farms increased from \$34 per acre to \$53; the estimated farm capital from \$17,020 per farm to \$27,118; the farm receipts from \$4,793 to \$8,415; the farm expenses from \$3,128 to \$4,704, and the estimated value of the farmer's own labor from \$476 to \$644.

For the colored tenants, the estimated capital increased from \$475 to \$1,065; receipts from \$922 to \$1,842; expenses from \$599 to \$999; and the value of the farmer's own labor from \$198 to \$367. The estimated capital of the landlord of the colored tenant increased from \$2,719 per farm to \$4,991, and his annual expense per tenant farm from \$34 to \$86.

On farms of approximately the same size, and with approximately the same yield of cotton per acre, farm earnings were highest where the percentage of crop land in cotton was highest.

The farmers who used the most man labor and the most mule labor per acre, and who applied the most fertilizer, as a rule got the highest yields and the largest net earnings.

Average cost of producing cotton (per pound of lint) ;

1913----	11.8 cents	{ Cash, 7.5 cents. Other, 4.3 cents.
1918----	23.2 cents	{ Cash, 14.3 cents. Other, 8.9 cents.

On farms of a given class or tenure, the cost of producing cotton per pound of lint decreased with increase of size of farm and yield per acre.

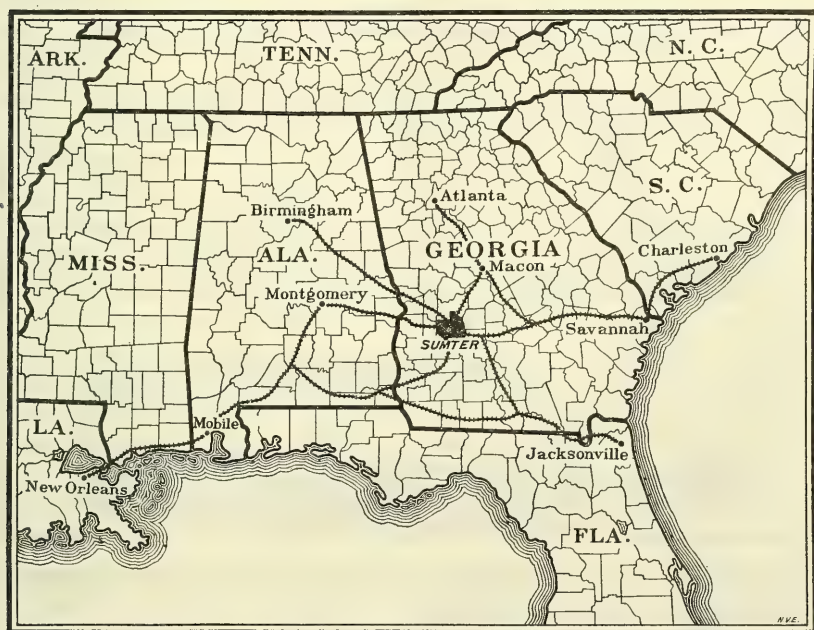


FIG. 1.—Map showing location of Sumter County, Ga., where an analysis of the business of 534 farms was made for 1913 and of 550 farms for 1918.

On farms with high yields, the cost of cotton per pound was generally lower than on farms with low yields, though the cost per acre was higher.

AREA STUDIED.

Sumter County is in the southwestern part of Georgia (see fig. 1). Americus, the county seat, situated near the center of the county, is about 150 miles south of Atlanta, 185 miles west of Savannah, and 95 miles north of the Florida State line.

The county was laid out in 1831 from part of Lee County. The first inhabitants came mostly from the older districts of the State.

The population in 1910 was 29,092, of which 7,849 were white and 21,243 were colored. In 1920 it was 29,640, of which 9,778 were white and 19,862 colored. The county in 1909 contained 291,840 acres, of which 276,834 were in farms. There were 92,822 acres of cotton grown in the county in 1909 and 70,448 acres in 1919. The land was originally owned in very large tracts, but during recent decades many of these large plantations have been cut up, so that there now exist many small and medium-sized farms.

The county is served by two railroads, which furnish very good transportation facilities. Practically all the main wagon roads of the county are in excellent condition.

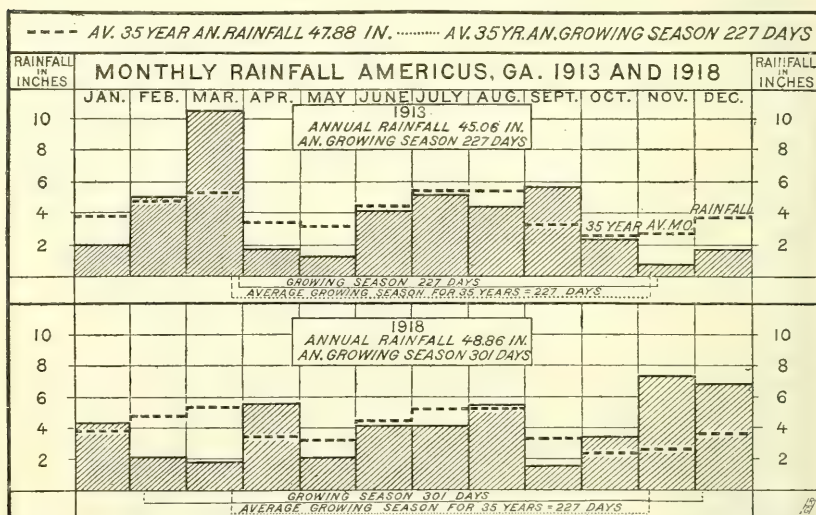


FIG. 2.—Monthly and annual rainfall at Americus, Ga., for 1913 and 1918, and the 35-year average. Also the growing season in days from the last killing frost in the spring to the first killing frost in the fall.

SOILS AND TOPOGRAPHY.

Sumter County lies wholly within the Coastal Plain, its northern boundary being 28 miles south of the Piedmont line.

The soils of greatest importance to agriculture include those derived from material washed down from the Piedmont Plateau and from soft limestone underlying all parts of the county. These soils represent 88.7 per cent of the land area of the county; and while ranging from light sands to heavy clays, are predominantly sandy. Some of these sand soils are of higher value than most sands, as they have retentive subsoils and produce good yields of many of the crops grown in the county.³

³ Soil Survey, Sumter County, Ga., U. S. Department of Agriculture, Field Operations of the Bureau of Soils, 1910.

The topography of the county varies from very rolling in the northern part of the county to gently rolling or flat in the southern part.

CLIMATE.

The climate is characterized by short, mild winters and long summers with rather high humidity, but not extremely hot. The rainfall as recorded at Americus by the United States Weather Bureau was 45.06 inches in 1913 and 48.86 inches in 1918, with an average of 47.88 inches for the 35-year period from 1884 to 1918, inclusive. The length of growing season from last killing frost in spring to first

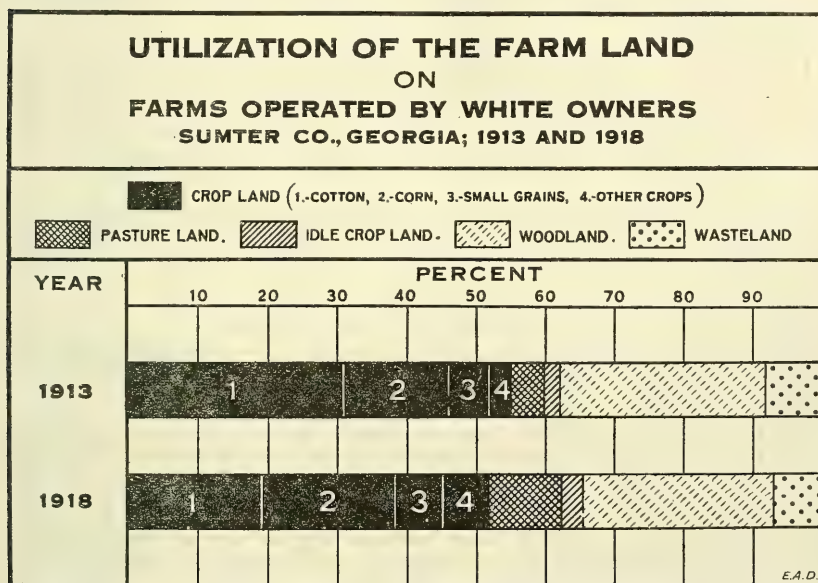


FIG. 3.—Over 50 per cent of the farm land was used for growing crops each year. The greater part of the remainder lay as woodland. The acreage in cotton was reduced about one-third in 1918 and that of corn increased about one-third. The acreage in pasture in 1918 was about twice that of 1913. Thus more land was used for growing feed crops and for pasture for the increased amount of live stock in 1918.

killing frost in fall and the distribution of rainfall by months are shown in figure 2.

UTILIZATION OF THE LAND.

The way the land on the Sumter County owner farms is utilized is shown in figure 3. Here are given the proportions of the farm land that were used for crops, for pasture, that lay as idle land, as woodland, and as waste land for the farms operated by white owners in 1913 and 1918. This figure also shows the proportions of the crop land that were used each year for growing cotton, corn, small grains, and other crops. Over 50 per cent of the total land area was used for

growing crops. Both crop area and woodland area showed slight decreases in 1918, the falling off being offset by an increase in pasture area. Woodland occupied 30 per cent of the total acreage in 1913 and 28 per cent in 1918.

FARM ORGANIZATION AND BUSINESS ANALYSIS OF FARMS.*

Of the 534 farms from which data were obtained in 1913, 268 were operated by white owners, 31 by colored owners, 49 by white tenants, and 186 by colored tenants. Of the 550 farms in 1918, 280 were operated by white owners, 48 by colored owners, 56 by white tenants and 166 by colored tenants. "Croppers" are not counted as tenants, but as farm laborers.

The relative importance of the white and colored owner and tenant farms included in this study is shown in Plate I. From the standpoints of crop acreage and crop production the farms operated by white owners are of greater importance than indicated by the

* In order to present the data clearly, certain terms which will be used throughout the following discussion are here defined. It is important that the reader thoroughly understand these terms, as such understanding will materially assist in the interpretation of the results.

Tilled area.—The number of acres of the farm devoted to raising crops.

Owner.—The man who owns the farm or one hired in his stead.

Tenant.—Locally known as "renter." One who operates land owned by somebody else, furnishing all labor and equipment, directing operations, and paying rent in cash or a fixed amount of cotton.

Landlord.—The owner of a leased farm.

Farm capital.—The value at the beginning of the farm year of all real estate, machinery, live stock, and other property used to carry on the farm business. It includes the value of the farm dwelling, but not of the household furnishings.

Receipts.—Proceeds from the sale of crops, the increase from stock, and the receipts from outside labor, rent of buildings, etc. The increase from stock is found by subtracting the sum of the amount paid for stock purchases and the inventory value at the beginning of the year from the sum of the receipts from stock products, sales of live stock, and the inventory value at the end of the year. If the value of crops or supplies on hand at the end of the year was greater than at the beginning, the difference is considered a receipt.

Expenses.—Annual expenditures made in carrying on the farm business, including the value of the unpaid labor performed by members of the family and depreciation on buildings and equipment. If the value of crops or supplies at the end of the year was less than at the beginning, this is considered an expense. Household or personal expenses are not included.

Farm income.—The difference between receipts and expenses. It represents the net amount available for the farmer's living above the value of family labor, provided he has no interest to pay on mortgages or other debts.

Labor income.—The amount that the farmer has left for his labor after 7 per cent interest on the farm capital is deducted from the farm income. It represents what he has earned as a result of his year's labor after the probable earning power of his investment has been deducted. In addition to labor income, the farmer receives a house to live in, fuel (when cut from the farm), garden products, milk, butter, eggs, etc. A "minus" labor income means that the farmer received no returns above food products, fuel, and house rent for his year's labor, and that he lacked the amount indicated of paying 7 per cent interest on the farm capital.

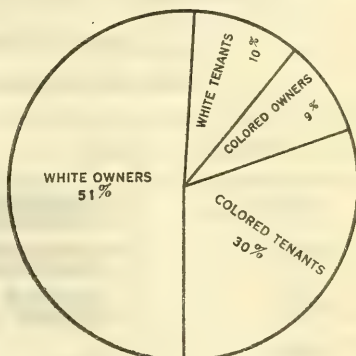
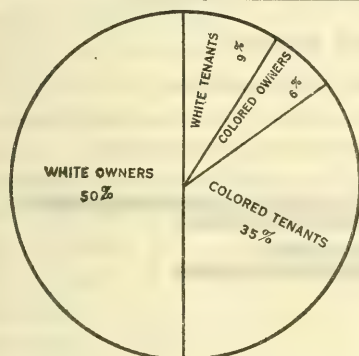
Per cent return on capital.—The rate returned on the farm capital after the value of the farmer's labor is deducted from the farm income. It represents what the capital earned after all expenses have been deducted and the farmer has received a fair wage for his labor. When the per cent return on the capital is preceded by the minus sign, it means that the farmer did not realize even fair wages for his own labor and management, thus leaving nothing for the earnings on the farm capital.

RELATIVE IMPORTANCE OF THE SEVERAL TENURES IN THIS STUDY SUMTER CO., GEORGIA 1913 AND 1918

AS TO NUMBER OF FARMERS

1913

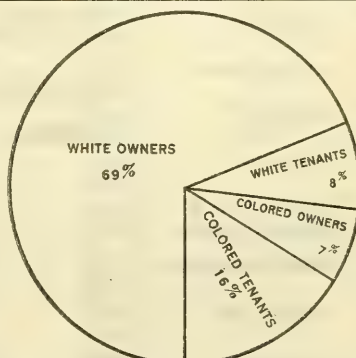
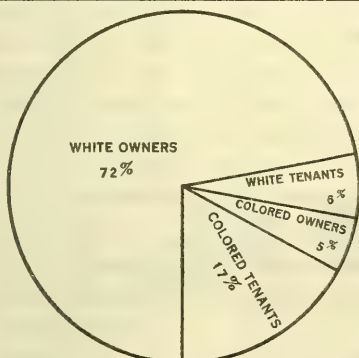
1918



AS TO CROP ACREAGE

1913

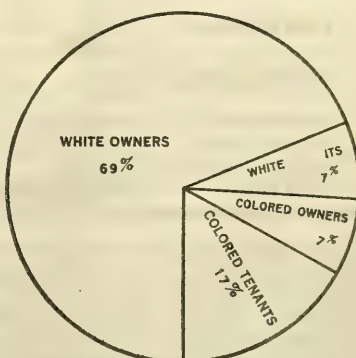
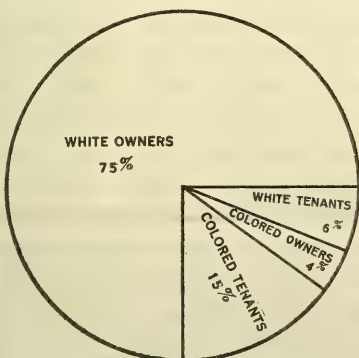
1918



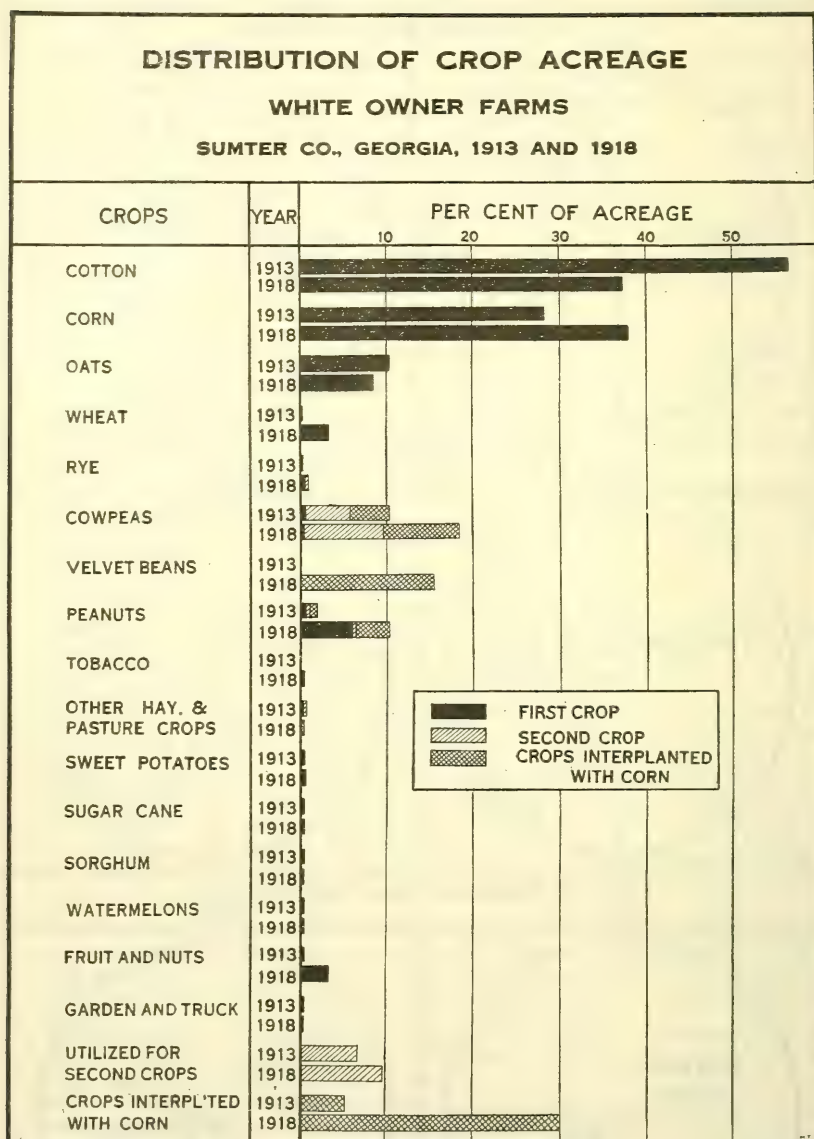
AS TO PRODUCTION OF COTTON

1913

1918



From the standpoints of crop acreage and production of cotton, the farms operated by white owners were of greater importance than was indicated by the number of farmers and those operated by colored tenants of less importance. Farms operated by white owners represented about one-half of the farms, but more than two-thirds of the crop acreage, and they produced almost three-fourths of the cotton. Farms operated by colored tenants represented about one-third of the farms, but only about one-sixth of the crop land, and they produced scarcely one-sixth of the cotton.



More than one-half of the crop acreage was planted to cotton in 1913 and more than one-third in 1918. In 1913 the acreage planted to corn was about two-thirds that planted to cotton, but in 1918 there was about an equal acreage of each crop. From 1913 to 1918 the acreage in oats was decreased and that of wheat and rye increased. About one farm in fifty was producing wheat in 1913 and two farms in three in 1918. The acreage planted to cowpeas, velvet beans, and peanuts was much greater in 1918 than in 1913. Most of the cowpeas and velvet beans and about one-half of the peanuts were grown interplanted with corn, or as second crops following small-grain crops; thus the acreage utilized for growing second crops and interplanted crops in 1918 was greatly increased over that of 1913.

number of farms, and those operated by colored tenants of less importance. While the farms operated by white owners represent about one-half of the total number of farms, they represent more than two-thirds of the crop land and they produce almost three-fourths of the cotton. The farms operated by colored tenants represent about one-third of all the farms, yet they represent only about one-sixth of the crop land and produce scarcely one-sixth of the cotton.

The owner-operators include three classes, namely, the "straight owner," or one owning all his farming land and having entire supervision of it; "owner renting additional," or one operating his own land and also renting additional land which he operates along with his own land as one farm unit; and "owner with part rented out," or one renting out part of his own land. Renting out a part of the farming land was practiced frequently by owners of the larger farms in order to shift a share of the responsibility and risk. The tenants furnished the working capital, performed all the labor, and gave the owners a fixed amount of lint cotton or very rarely a stipulated cash rent, or a fixed share of the crops, for the use of the land. The farms operated by tenants were comparatively small, but some of the farms operated by owners comprised thousands of acres.

In the operation of these larger farms two distinct methods of employing the necessary labor have been developed, namely, (1) the wage-hand system, and (2) the share-cropper system.⁵

Table 2 shows the percentage of the total crop acreage grown by wage labor and that by share-cropper labor. There was a tendency in 1918 to grow more of the crops by the latter system than by the former, primarily on account of the difficulty in getting men to work as wage hands.

Operating the large farms entirely with wage labor is a serious task that only the exceptional farmer will undertake. It is about as profitable and less hazardous to employ both wage hands and share-croppers and also rent out a part of the crop land. The scarcity of efficient labor willing to work for wages is a limiting factor in this regard. The negroes, in general, seem to prefer the share-of-crops system, not only because it gives a measure of independence, but also because it gives an opportunity for the employment of the entire family.

Under the wage-hand system the laborers live on the farms and are usually furnished rations in addition to a stipulated cash wage for about seven months of the year. During the harvesting season they work as day laborers or contract laborers. Other members of the laborer's family are usually employed during the earlier part of the

⁵ In this bulletin share croppers have not been included as tenants but are included as laborers. It should be noted that in this the practice of the U. S. Bureau of the Census has not been followed. In the census figures the share croppers are counted as tenants.

season as day laborers for chopping, hoeing, etc., and during the cotton-picking season as contract laborers.

The share croppers also live on the farms, but they assume responsibility for all the labor on the crops they grow. As pay for the labor they usually receive one-half of the crops, less one-half the expense for fertilizer and ginning, while the operator furnishes all capital, pays all expenses other than those paid by the cropper, and has full supervision of the business. Because the share cropper furnishes little but labor he bears a close relation to the wage hand, the only difference being that he receives a share of the crops for his services instead of cash wages. In this study the value of the croppers' share of crops, less the expense paid by the croppers, has been counted as a labor expense to the farm operator. This was found the more feasible method because the farm operator's own labor, his buildings, equipment, mules, and cash outlay are for the production of both wage and cropper crops. Included in this study were 17 plantations in 1913 and 14 in 1918 which were operated by managers hired to assume entire management and direction of the farm operations, instead of the owners. These farms were larger than the average; 12 of them in 1913 and 10 in 1918 had over 450 acres of tilled land. The managers of these farms were considered in place of the owners, thereby making the farms comparable with others of similar size.

SIZE OF FARMS.

The white farmers, as a rule, operated the large farms. (See Table 1.) One out of every five had over 250 acres of tilled land, as against one in 50 of the colored farmers. More than one-half of the white farmers, but less than one-fourth of the colored farmers, had over 100 acres of crops. More than one-half of the owners, but less than one-fourth of the tenants, had over 100 acres of crops.

TABLE 1.—*Size of farms operated by white and colored owners and tenants, Sumter County, Ga., 1913-1918.*¹

	Year.	Number of farms under each size-group.						Total farms.
		50 tilled acres or under.	51 to 100 tilled acres.	101 to 150 tilled acres.	151 to 250 tilled acres.	251 to 450 tilled acres.	Over 450 tilled acres.	
White owners.....	1913	36	64	56	47	30	35	268
	1918	37	83	43	50	32	35	280
White tenants.....	1913	17	17	10	3	2	.....	49
	1918	10	23	12	6	5	.....	56
Colored owners.....	1913	3	13	6	5	3	.....	31
	1918	9	20	7	9	2	1	48
Colored tenants.....	1913	96	68	18	4	.....	.....	186
	1918	62	69	26	8	1	.....	166

¹ Since the farms in this area show a wide range in size and a wide variation in the proportion of the total area in woodland and crop land, the number of acres of tilled land was found a better measure of the size of business than that of the total farm area. In all tables in this bulletin where the farms are grouped by size the acres of tilled land are used as the basis.

No striking change in this respect took place in the period between 1913 and 1918. That fewer farms were operated by colored tenants in 1918 than in 1913, as shown in the table, should not be construed to mean that colored tenants are on the decrease; it happened that fewer of such operators were visited in 1918 than in 1913. For the same reason it should not be understood that the number of colored tenants operating farms of 50 tilled acres or under, is decreasing.

CROPS GROWN.

The long growing season, together with other favorable conditions, enables the farmers of this area to grow a large variety of crops, and in many cases to use the land for more than one crop during the year. Table 2 shows the relative importance of the many crops grown, in point of area occupied. Cotton and corn were the only crops grown occupying over 10 per cent of the crop area. Comparing 1913 and 1918, the areas of cotton and oats were decreased, while those of corn and other crops of significance were increased. There was a big increase in 1918 over 1913 in the area used for second crops and for interplanted crops, especially on the white-owner farms, where the second crop was increased from 7 to about 10 per cent, and the interplanted corn acreage from 5 per cent to 30. (See also Plate II.)

From the standpoint of the utilization of labor it would seem that the change in organization that has been brought about is an important advantage. The decreased acreage of cotton and the increased acreage of corn, small grains, peanuts, velvet beans, and hay allows a better distribution of labor through the summer months and the increase in live stock, especially hogs, aids materially in supplying productive labor for other periods of the year. The change, however, has not materially decreased the amount of labor necessary per farm, the average months of labor per farm on the white-owner farms in 1913 being 95 and in 1918, 91.

COTTON.

Cotton was, of course, the crop of greatest importance, occupying a larger acreage than any other crop, both in 1913 and in 1918, but with a large reduction in 1918 from 1913, namely 33 per cent by white owners and 20 per cent by colored tenants. This change is attributable to several influences, prominent among which were the invasion of the bollweevil, the increased cost of labor and materials in producing cotton with an uncertainty of price, and an improved outlook for the profitable production of corn, peanuts, and hogs.

The bollweevil appeared in Sumter County in 1915, but up to and including 1918 the damage had been much less than had been suffered in many other cotton-growing sections. The farmers' estimates in 1918 as to the reduction in yields on account of bollweevil ranged

from none to one-third. That is to say, many of the farms had thus far not been infested with this pest, while others had suffered serious loss. The data obtained by the Bureau of Crop Estimates showed that for the State of Georgia as a whole the loss due to the bollweevil in 1913 was only one-tenth of 1 per cent, while in 1918 it was 11 per cent

TABLE 2.—Percentage utilization of crop land, Sumter County, Ga., 534 farms in 1913 and 550 in 1918.

	White owners.		White tenants.		Colored owners.		Colored tenants.	
	1913	1918	1913	1918	1913	1918	1913	1918
Number of farms.....	268	280	49	56	31	48	186	166
Crop acres per farm.....	179	181	85	102	107	111	59	72
Per cent of crop area.								
Cotton:								
First crop.....	56.8	37.1	63.3	44.6	61.6	47.9	65.5	52.4
Second crop.....	.1	.2	.2	.1	.5	.1		
Interplanted.....		1.1						
Corn for grain:								
First crop.....	28.0	36.7	26.3	39.3	29.6	40.0	26.9	36.4
Second crop.....	.1	.2	.1	.7		.1		.1
Interplanted.....		1.0				.4		
Oats for grain: First crop.....	9.3	8.3	5.4	4.4	3.1	3.1	2.6	3.1
Wheat for grain: First crop.....	.1	3.6	.1	3.2	.1	2.6		2.0
Rye for grain: First crop.....	.1	.3		.1				
Cowpea seed: Second crop.....		.1	2.4			1.4	.2	.1
Peanuts for market:								
First crop.....	.2	4.9		4.4	.3	1.6	.2	1.4
Second crop.....		.4		.2	.3	.1		
Interplanted.....		1.0						
Hay and annual pasture:								
Cowpeas—								
First crop.....	1.0	.6	.3	.2	.4	.2	.5	.4
Second crop.....	5.8	8.8	5.5	5.0	3.1	3.9	1.6	4.4
Interplanted.....	4.2	8.9	.2	8.7	8.1	15.4	3.6	7.4
Velvet beans—								
First crop.....	(1)	(1)						(1)
Second crop.....	(1)							
Interplanted.....		15.6		11.8		4.6		5.4
Peanuts—								
First crop.....	1.0	1.4	1.3	1.2	.4	.8	.3	1.4
Second crop.....	.2	.1	.5	.2		.1	.1	(1)
Interplanted.....	.9	2.4		2.0	.1	2.3	.1	1.1
Total hay and annual pasture—								
First crop.....	3.7	3.6	3.4	1.9	3.6	2.6	3.0	2.9
Second crop.....	6.7	9.2	7.5	5.4	3.5	4.6	2.0	5.0
Interplanted.....	5.1	26.9	.2	22.5	8.8	22.3	3.9	14.0
Sugar cane and sorghum for sirup:								
First crop.....	.3	.4	.2	.3	.4	.5	.4	.4
Sweet potatoes: First crop.....	.3	.5	.5	.6	.5	.6	.5	.7
Watermelons: First crop.....	.2	.2	.1	.7	.2	.2	.3	.2
Castor beans: First crop.....								.1
Tobacco: First crop.....		.1						
Fruit and nuts: First crop.....	.1	3.5				.4		
Garden and truck: First crop.....	.9	.8	.7	.5	.6	.5	.6	.4
Grown by wage labor: ¹								
First crop.....	52.9	51.8	71.3	62.0	69.9	70.5	90.7	87.6
Second crop.....	6.9	9.7	10.1	6.4	4.3	5.8	2.2	5.2
Interplanted.....	4.9	17.4	.2	16.1	8.4	18.7	3.9	12.6
Grown by cropper labor:								
First crop.....	47.1	48.2	28.7	38.0	30.1	29.5	9.3	12.4
Second crop.....		.2	.1			.4		
Interplanted.....	.2	12.6		6.4	.4	4.1		1.4
Total:								
First crop.....	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Second crop.....	6.9	9.9	10.2	6.4	4.3	6.2	2.2	5.2
Interplanted.....	5.1	30.0	.2	22.5	8.8	22.8	3.9	14.0

¹ Less than one-tenth of 1 per cent.

² Including crops grown by the farmers' own labor and that of his family.

Tenants stuck closer to cotton than owners. The tenants applied their labor and capital to the production of that crop with which they were most familiar and had had the most experience, naturally feeling that they could ill afford to experiment with new systems and practices.

CORN.

Corn was second only to cotton in acreage and was the principal grain feed. It was also quite extensively used as a family food. Comparing owner and tenant farms, the relation of the corn area to the crop acreage, as a whole, did not vary materially in 1918 from 1913. The variation is shown in a comparison of years rather than of tenures. In 1913 there was about one-half as much land in corn as in cotton, while in 1918 there was practically as much land in the one as in the other on the white-owner farms, and about three-fourths as much on the farms of the other groups.

SMALL-GRAIN CROPS.

The small-grain crops (oats, wheat, and rye), taken together, were next to corn in first-crop acreage. Of these oats occupied by far the greatest acreage. The colored tenants devoted little attention to the production of oats, many of them having but small patches. The tendency in 1918 on both owner and tenant farms was toward a reduction in the oat acreage. It is the general practice in this area to harvest the oats and feed them in the sheaf, although some are thrashed before being fed. Occasionally oats were harvested for hay, but not over 10 per cent at most of the acreage was handled in this way.

Of the 534 farms studied in 1913 only 15 were producing wheat, while in 1918 7 out of every 10 farms were producing wheat. Wheat was grown more frequently by owners than by tenants. The acreage devoted to wheat was usually small, the main object being to grow the crop for flour. About 30 per cent of the farms growing wheat in 1918 sold a share of the crops, but 68 per cent of the sales were less than 50 bushels per farm. The farms growing wheat in 1913 had from 1 to 5 acres, with an average of only 3 acres per farm. In 1918 the acreage per farm ranged from 1 to 80 acres, and averaged 6.25 acres. Only one-tenth of 1 per cent of the entire crop land on owner or tenant farms was in wheat in 1913, and over 2 per cent in 1918. Undoubtedly one of the outstanding reasons for the increased wheat acreage was the difficulty of obtaining flour through the war period. It would seem probable, however, that, in view of the change in organization making more of the crop acreage available for grain crops, wheat should continue to hold a more important place than in the past.

There was an increase in the number of farmers raising rye in 1918 as compared with 1913, but, with this increase, only 1.1 per cent of the crop area in 1918 on the white-owner farms was in rye. Although a part of the rye was harvested for grain, it was used more frequently for winter and early spring pasture.

COWPEAS.

Cowpeas have an important place in the cropping system of Sumter County. The fact is they can be made to fit advantageously into almost any cropping system as a first crop, as a second crop, or as an intertilled crop. Furthermore, cowpeas may be used for hay, for seed, or for pasture, or in combination with velvet beans, sorghum, or other crops for a hay or grazing crop. Being a leguminous crop which succeeds on practically all soils in this area, the cowpea plays an important part in adding nitrogen to the soil and improving its mechanical condition.

In 1913 the cowpea was the crop most generally used as a second crop, following small grains and for planting with corn. In 1918 its use in this way was even more pronounced.

Cowpeas occupied 11 per cent of the crop area on white-owner farms in 1913, and 18 per cent in 1918. They were seldom grown as a first crop, about one-half of the acreage being grown after small grains and harvested for hay; the other half being interplanted with corn, some of the seed being picked, and the rest of the seed and the vines left on the ground for pasture or to be plowed under. White owners devoted the most attention to the cowpea.

VELVET BEANS.

The velvet bean is one of the most important crops of recent introduction in this area and is becoming well established in the cropping system. It yields well and may be utilized in a number of ways. It was used as an annual green manure crop, as a seed crop, as a hay crop, and as a fall and winter pasture crop. Probably the two most important uses of the velvet bean here were as a grazing crop for cattle and hogs during the fall and winter months and as a soil improver. It is usually grown in combination with corn or other crops. When the velvet bean is pastured practically all the material in the crop is returned to the soil and its value as a means of maintaining or increasing crop yields is becoming well recognized in this area.

In 1913 only 4 out of 534 farmers were growing velvet beans, while in 1918 348 out of 550 farmers were growing them. They were more generally grown by white farmers than by colored farmers. Practically all the velvet beans grown were planted with corn and pas-

tured, although many farmers picked part or all of the pods. In 1918 almost 50 per cent of the corn acreage on the white-owner farms was interplanted with velvet beans, while not over 15 per cent of the colored tenants were following this practice. The colored owners interplanted a much larger proportion of their corn acreage to cowpeas than to velvet beans.

PEANUTS.

During the past few years the changes in economic conditions have been very favorable to the increased production of peanuts. In 1913 practically all the peanuts were used for stock feeding, but since that time conditions have changed so as to make them of more value as a feed crop, owing to the increased production of hogs, and of much greater importance as a cash crop. When the crop is grazed off, it aids in maintaining soil fertility.

In 1913 less than 2 per cent of the crop land was planted to peanuts, and the peanuts were used almost entirely for feed. At that time about one-half the peanuts were grown as first crop and one-half planted with corn. In 1918 some 10 per cent of the crop land was planted to peanuts on the white-owner farms and from 4 to 8 per cent under the other tenures. Over one-half of these were grown as first crop and most of the others planted with corn. A few were grown as a second crop, following the small grain. The increase in importance of this crop as a cash crop is indicated by the sales of peanuts in 1918. On the white-owner farms such sales amounted to \$2 per farm in 1913 and \$352 in 1918. About one-half of the peanut acreage in 1918 was sold as cash crop; the remainder was used as feed for hogs.

HAY AND PASTURE CROPS.

Cowpeas, velvet beans, and peanuts, previously discussed separately, made up 95 per cent of the acreage in hay and pasture crops, the greater part of which were grown as second crop after small grains, or planted with other crops usually corn. Small acreages of a number of other crops, such as oats, wheat, rye, sorghum, corn, millet, rape, and crab grass, were also used by some of these farmers for these purposes.

OTHER CROPS.

Sugar cane, sweet potatoes, and watermelons, raised mainly for farm and home use, together occupied about 1 per cent of the total crop area. There was a small increase in the acreage of these crops in 1918, particularly among the white farmers. Sweet potatoes were in particular favor for finishing hogs, because they produce more solid meat than equal areas of peanuts.

A number of farmers devoted small acreages to sorghum in both 1913 and 1918. In 1913 sorghum was used almost exclusively as a feed crop, but in 1918 the crop from 29 per cent of the acreage was made into sirup.

No tobacco was reported in 1913, but in 1918 tobacco was reported on 5 white-owner farms. One farm had 25 acres in tobacco, and each of the others less than 10 acres. The yield per acre ranged from 500 pounds to almost 900 pounds, averaging about 700 pounds.

GARDEN AND TRUCK CROPS.

Most of the farmers had small areas in garden or truck for family use and for supplying the hired labor. The average acreage in garden and truck for any farm was less than 1 per cent of the total crop acreage, and showed but little variation. More croppers had gardens in 1918 than in 1913. In fact, some farmers had come to require their croppers to grow a part or all of their own vegetables, in order to limit their need for credit and give them a better chance of breaking even should the boll weevil or other conditions cause heavy losses.

SECOND CROPS.

In 1918 much more of the crop land was used for growing second crops or interplanted crops than in 1913. It is not thought that the longer growing season of 1918 was an important factor in increasing the acreage of second crops and interplanted crops, because this change seems to be in entire harmony with the other changes in the organization of these farms. The greatest increase in utilizing the land for this purpose was among the white owners. Furthermore, the greater part of such crops was grown on land operated by wage labor. This is in harmony with other changes in the farm organization for the several tenures. White owners showed the greatest tendency toward live-stock farming, consequently, more feed crops were required on their farms than on those of other classes.

CROPS INTERPLANTED WITH CORN.

It has been pointed out that cotton and oats were the two more important crops that show a decreased acreage in comparing the results of 1913 and 1918. Those showing considerable increases were corn, wheat, cowpeas, velvet beans, and peanuts.

One of the very important changes in farm practice noted is the tendency to interplant more of the corn acreage with velvet beans, cowpeas, and peanuts. The growing of some leguminous crop between the rows of intertilled crops, such as corn or cotton, affords the simplest system of growing crops for soil improvement. It is

an inexpensive and easy means of increasing crop yields, as well as crop acreages; and undoubtedly this practice will be, and should be, followed in greater measure on many farms in this area. Corn lends itself to the practice of interplanting better than any other crop common to this area. (See Table 3.)

TABLE 3.—Percentage of corn acreage interplanted with other crops, Sumter County, Georgia, 1918, 550 farms.

	Acres in corn per farm.	Per cent of corn acreage interplanted with—							Total.	Per cent of corn acreage not interplanted
		Velvet beans.	Cow-peas.	Pea-nuts.	Velvet beans and cow-peas.	Velvet beans and pea-nuts.	Cow-peas and pea-nuts.	Velvet beans, cow-peas, and pea-nuts.		
White owners:										
Wage corn ¹	35	40	17	2	7	9	1	1	77	23
Cropper corn.....	34	28	22	3	5	4	1	1	64	36
Total corn.....	69	35	20	2	6	6	1	1	71	29
White tenants:										
Wage corn ¹	26	25	26	6	2	3	1	.....	63	37
Cropper corn.....	15	31	10	1	.....	.....	.....	.....	42	58
Total corn.....	41	27	20	4	1	2	1	.....	55	45
Colored owners:										
Wage corn ¹	33	12	35	5	3	2	4	.....	61	39
Cropper corn.....	12	2	37	.....	.....	.....	.....	.....	39	61
Total corn.....	45	10	35	4	2	1	3	.....	55	45
Colored tenants:										
Wage corn ¹	23	13	20	3	2	1	1	.....	40	60
Cropper corn.....	3	16	16	1	.....	.....	.....	.....	33	67
Total corn.....	26	14	20	2	1	1	1	.....	39	61

¹ Wage corn is that grown by wage hands and by the farmer and his family.

In 1918, 35 per cent of the corn acreage of the white owners was interplanted with velvet beans, 20 per cent with cowpeas, and 16 per cent with other crops, making in all 71 per cent of the corn area interplanted with other crops. The white tenants and colored owners each interplanted 55 per cent of the corn acreage with other crops, while the colored tenants utilized only 39 per cent of the corn area for these crops. Velvet beans were used more extensively on the owner farms than on the tenant farms.

CROP YIELDS.

Cotton, the small grains, cowpea hay, and cane sirup gave lower yields in 1918 than in 1913, corn about the same yields each year, and peanuts and sweet potatoes higher yields in 1918 than in 1913. As a rule, the wage land returned higher yields than the cropper land. (See Table 4.)

TABLE 4.—Yield per acre of the principal crops, Sumter County, Georgia, 534 farms in 1913 and 550 in 1918.

	White owners.		White tenants.		All white farmers.		Colored owners.		Colored tenants.		All colored farmers.	
	1913	1918	1913	1918	1913	1918	1913	1918	1913	1918	1913	1918
Cotton grown by wage labor.....pounds lint..	302	284	225	209	291	270	195	203	212	193	209	195
Cotton grown by share-cropper labor.....pounds lint..	264	244	231	213	262	242	186	166	206	176	196	171
All cotton.....do....	279	256	227	211	274	251	192	189	211	191	207	190
Corn grown by wage labor, bushels.....	17	16	12	12	16	16	9	9	9	10	9	10
Corn grown by share-cropper labor.....bushels..	12	13	13	12	12	13	8	7	7	8	8	8
All corn.....do....	15	15	12	12	15	14	9	9	8	10	9	9
Oats.....do....	25	21	28	15	25	21	14	10	12	12	13	11
Wheat.....do....	11	9	18	7	15	8	8	7	6	8	7	7
Cowpea hay.....tons..	.73	.54	.64	.60	.72	.55	.57	.53	.58	.50	.58	.51
Peanuts.....do....	.20	.30	.20	.30	.20	.30	.12	.20	.13	.11	.13	.14
Tobacco.....pounds		703				703						
Cane sirup.....gallons.	184	161	166	133	183	159	123	102	128	102	127	102
Sweet potatoes.....bushels.	91	112	76	122	90	113	74	107	76	102	75	104

In considering the wide difference in yield when comparing the various classes of farms shown in the table or when comparing the wide range on individual farms within any one class, many factors should be taken into account, some of which, because of lack of data, can not yet be properly weighed. While there is no great difference in the quality of soil of the various farms throughout this area, there has long been wide variation in the farm practice followed for soil improvement. Some farms have been operated year after year with little or no attention to fertility maintenance and are at this time in a very low state of productivity. Keeping up the productiveness of these farms is a problem of much importance and one which is obviously receiving increased attention. The farmers of this area have to depend mainly upon growing crops for supplying organic matter, which is vitally important in maintaining the productiveness of these lands. With the long growing season a large quantity of organic matter is required each year. Many of the soils also lose considerable from erosion unless they are protected. By plowing under cotton stalks and cornstalks and leguminous crops, together with the aid of fertilizer, the more progressive farmers are keeping their land in a comparatively high state of fertility. The farmers that were found conserving manure, plowing under leguminous crops to supply vegetable matter, using a good application of fertilizer, and practicing the best tillage methods were the ones realizing the better yields and the higher returns.

Both white owners and colored renters used less fertilizer per crop acre in 1918 than in 1913 on cotton as well as on other crops, and,

as already pointed out, they had lower yields of cotton. However, when the farms are classified in groups upon the basis of fertilizer application a definite relation between the amount of fertilizer applied and yields returned each year is apparent. The quantity of fertilizer used per acre was reduced 37 per cent. (See Table 5.)

TABLE 5.—Amount of fertilizer applied per crop acre and yield of cotton and corn, Sumter County, Ga.

Fertilizer applied.	Number of farms.	Fertilizer applied per crop acre.	Yield per acre.		Tilled acres per farm.	Labor income.	Per cent return on capital.
			Lint cotton.	Corn.			
By white owners, 1913:		<i>Pounds.</i>	<i>Pounds.</i>	<i>Bushels.</i>			
200 pounds and less.....	37	171	228	12	157	\$20	4.4
201-300 pounds.....	78	257	258	13	186	250	5.8
301-400 pounds.....	69	350	285	14	192	428	6.5
401-500 pounds.....	43	443	314	17	337	739	6.3
Over 500 pounds.....	41	620	339	18	315	1,108	7.7
By white owners, 1918:							
100 pounds and less.....	47	64	211	12	133	914	8.5
101-200 pounds.....	119	153	232	13	185	841	9.2
201-300 pounds.....	62	243	260	14	257	2,270	9.6
301-400 pounds.....	28	357	267	15	383	3,777	13.1
Over 400 pounds.....	24	525	305	20	318	4,921	15.4
By colored tenants, 1913:							
200 pounds and less.....	47	155	172	8	61	214	.....
201-300 pounds.....	86	250	203	8	54	331	.....
Over 300 pounds.....	53	350	250	11	67	443	.....
By colored tenants, 1918:							
100 pounds and less.....	29	79	154	8	77	798	.....
101-200 pounds.....	90	151	181	11	73	1,066	.....
Over 200 pounds.....	47	249	230	12	71	1,428	.....

One of the reasons for the lighter applications of fertilizer in 1918 was the higher cost per ton, but even with the advance in price the heavier applications seem to have brought profitable gains, as indicated by the higher average labor incomes and higher per cent returned on capital of the farms making the heavier applications of fertilizer.

In case of the owners shown in this table, however, it should not be inferred that this entire increase in labor income is due to increased application of fertilizer, for it will be observed that those farms applying the larger amount of fertilizer are the larger farms, and for this reason alone would naturally be expected to return the larger labor incomes. It undoubtedly is true that a number of factors aided in returning the higher labor incomes, but the fact that the better farmers do use the larger applications of fertilizer would seem to justify the practice.

For comparison of the yields of the more important crops grown in Sumter County with those for the entire State, and to aid in determining the relation of the yields in 1913 and 1918 to those of other years, crop yields for the State of Georgia, as reported by the Bureau of Crop Estimates, are shown for the 10-year period 1911

to 1920. (See Table 6.) The yield of cotton in 1913 was very close to that of the State average for the five-years 1911 to 1915, but the yield for 1918 was much above that of the average for the five-year period 1916 to 1920. The average yield for the latter five-year period fell more than 20 per cent below that of the former. The yield per acre of cotton for Georgia in 1913 is given at 82.6 per cent of normal, and in 1918 at 71.11 per cent. The losses from normal yield for each year are assigned to causes shown in Table 7.

TABLE 6.—*Yields of the more important crops in Georgia, 1911–1920.*

[Data from Bureau of Crop Estimates.]

	1911	1912	1913	1914	1915	5-year aver- age.	1916	1917	1918	1919	1920	5-year aver- age.
Cotton.....pounds..	240	159	208	239	189	207	165	173	190	152	138	164
Corn.....bushels..	16	14	16	14	15	15	16	16	15	14	15	15
Oats.....do.....	22	21	22	20	20	21	20	16	20	20	21	19
Wheat.....do.....	12	9	12	12	11	11	11	8	10	10	10	10
Rye.....do.....	10	9	10	9	9	9	10	8	9	9	10	9
Hay.....tons.....	1.35	1.35	1.40	1.35	1.15	1.32	1.15	1.03	1.24	1.10	1.15	1.13
Peanuts.....bushels..									28	25	34	1 ²⁹
Sweet potatoes.....do....	80	90	87	85	85	85	80	93	92	92	93	90

¹ Three-year average.TABLE 7.—*Causes assigned for subnormal yield of cotton in Georgia in 1913 and 1918 (normal assumed to be probable yield under favorable conditions).*

[Data from Bureau of Crop Estimates.]

	1913	1918
Per cent of normal yield.....	82.60	71.11
Per cent of loss.....	17.40	28.89
Per cent of loss due to adverse weather conditions.....	14.20	11.89
Deficient moisture.....	8.80	7.10
Excessive moisture.....	.70	1.38
Floods.....	.40	.14
Frost.....	1.10	.79
Hail.....	.60	.33
Hot winds.....	1.70	1.77
Storms.....	.20	.38
Not specified.....	.70	.....
Per cent of loss due to diseases.....	.80	3.34
Blight.....	.....	.40
Rust.....	.....	1.58
Rot.....	.30	.....
Wilt.....	.....	1.23
Not specified.....	.50	.13
Percent of loss due to insect pests.....	1.30	12.87
Army worms.....	.10	.....
Boll worms.....	.80	1.14
Boll weevil.....	.10	10.73
Cut worms.....	.20	.....
Red spiders.....	.....	.98
Chinch bugs.....	.....	.02
Not specified.....	.10	.....
Per cent of loss due to defective seed.....	.50	.....
Per cent of loss due to other causes.....	.50	.60
Per cent of loss due to unknown causes.....	.10	.19

Comparing Tables 4 and 6, it appears that Sumter County had a better yield of cotton than the State average, and a poorer yield of hay. The fact that Sumter County produces better yields of cotton than many other areas of the State is evidence that cotton should have an important place in the organization of Sumter County farms as long as cotton production is profitable in the State.

DISTRIBUTION OF FARM RECEIPTS.

Changes of considerable importance in the distribution of farm receipts took place from 1913 to 1918. Cotton with seed is of course the outstanding cash enterprise. Few other enterprises contributed as much as 5 per cent during either year, and most of them only 1 per cent or less. There was, however, a decline in the relative returns from cotton in 1918, and a noticeable increase in returns from peanuts, corn, and live stock, especially hogs.

Comparing the 1913 and 1918 results, the decrease in the receipts from cotton and the increase in corn, peanuts, and live stock were apparently due more to the change in farm organization, whereby the cotton enterprise was decreased and the other enterprise increased, than to changes in price relations. The details of these changes in farm receipts on farms operated by owners and tenants are shown in Table 8, while figure 4 represents graphically the distribution of farm receipts on the white-owner farms.

TABLE 8.—Average distribution of receipts on farms, Sumter County, Ga., 534 farms in 1913 and 550 in 1918.

	Owner farms.		Tenant farms.					
			Farm.		Tenant.		Landlord.	
	1913	1918	1913	1918	1913	1918	1913	1918
WHITE FARMERS.								
Number of farms.....	268	280	49	56	49	56	49	56
Average receipts per farm.....	\$4,793	\$8,415	\$1,971	\$4,011	\$1,580	\$3,222	\$394	\$905
Per cent of receipts from—								
Lint cotton.....	72.5	62.0	76.9	68.8	71.3	61.5	98.7	85.9
Cotton seed.....	10.8	11.4	12.1	13.7	15.1	17.0	.3	.3
Total cotton.....	83.3	73.4	89.0	82.5	86.4	78.5	99.0	86.1
Corn and fodder.....	3.0	5.0	2.1	4.1	2.6	4.9	.3	1.0
Oats.....	.9	.4	.6	.1	.8	.2		
Wheat.....		.8		.3		.4		
Rye.....	(1)	(1)						
Cowpea seed.....	.1	.1		.2		.2		
Hay.....	.5	.6	.6	.3	.7	.4		
Velvet beans.....		.1		.2		.2		
Peanuts.....	.1	4.0	.1	3.4	.1	4.2		
Tobacco.....		.5						
Sugar cane and sorghum sirup.....	.5	.9	.4	.4	.4	.5		.1
Sweet potatoes.....	.3	.3	.3	.3	.4	.3		
Watermelons.....	.1	.1	(1)	.5	.1	.6		
Fruit, nuts, truck, and garden.....	.1	.1	.1	.1	.1	.1		
Increase in feed.....	1.5	.8	3.3		4.1			
Total crops.....	90.4	87.0	96.5	92.4	95.6	90.5	99.3	87.2
Cattle and dairy products.....	.6	1.2	.6	.8	.8	1.0		
Hogs.....	1.7	5.6	.6	3.8	.7	4.7		
Poultry and eggs.....	.4	.3	.5	.6	.6	.8		
Total live stock.....	2.7	7.1	1.7	5.2	2.1	6.5		
Man and team labor.....	.2	.2	1.7	.6	2.1	.8		
Ginning and other machine work.....	1.3	.3	.1	.1	.1	.1		
Woodland products.....	1.0	.3	(1)	(1)	.1	(1)		
Rent.....	4.4	5.1		1.7		2.1	.7	12.8
COLORED FARMERS.								
Number of farms.....	31	48	186	166	186	166	186	166
Average receipts per farm.....	\$2,064	\$3,773	\$1,186	\$2,615	\$922	\$1,842	\$267	\$789
Per cent of receipts from—								
Lint cotton.....	73.7	76.2	82.9	79.8	77.9	71.9	98.9	96.9
Cotton seed.....	8.6	13.3	11.3	14.5	14.6	20.3		.6
Total cotton.....	82.3	89.5	94.2	94.3	92.5	92.2	98.9	97.5
Corn and fodder.....	2.0	1.7	.6	1.1	.8	1.3		.4
Wheat.....		.1						
Cowpea seed.....	.2	.6	.1	.2	.2	.2		(1)
Hay.....	.1		.1	(1)	.1	(1)		(1)
Velvet beans.....				.1		.2		(1)
Peanuts.....	(1)	.9		.6		.8		(1)
Sugar cane and sorghum sirup.....	.4	.4	.3	.2	.3	.3		
Sweet potatoes.....	.2	.1	.3	.1	.3	.2		
Watermelons.....	(1)	.1	.1	.1	.1	.2		
Fruit, nuts, truck, and garden.....	(1)	.1		(1)		(1)		
Increase in feed.....	2.4	.5	2.2	.6	3.0	.8		
Total crops.....	87.6	94.0	97.9	97.3	97.3	96.2	98.9	97.9
Cattle and dairy products.....	.9	1.0	.5	.6	.7	.9		
Hogs.....		1.1		1.1		1.4		.3
Poultry and eggs.....	.2	.5	.3	.3	.4	.4		
Total live stock.....	1.1	2.6	.8	2.0	1.1	2.7		.3
Man and team labor.....	1.5	.1	1.1	.4	1.4	.5		
Ginning and other machine work.....	2.2	.2	.1	.1	.1	.1		
Woodland products.....	.3	.3	.1	(1)	.1	.1		
Rent.....	7.3	2.8		.2		.4	1.1	1.8

¹ Less than one-tenth of 1 per cent.

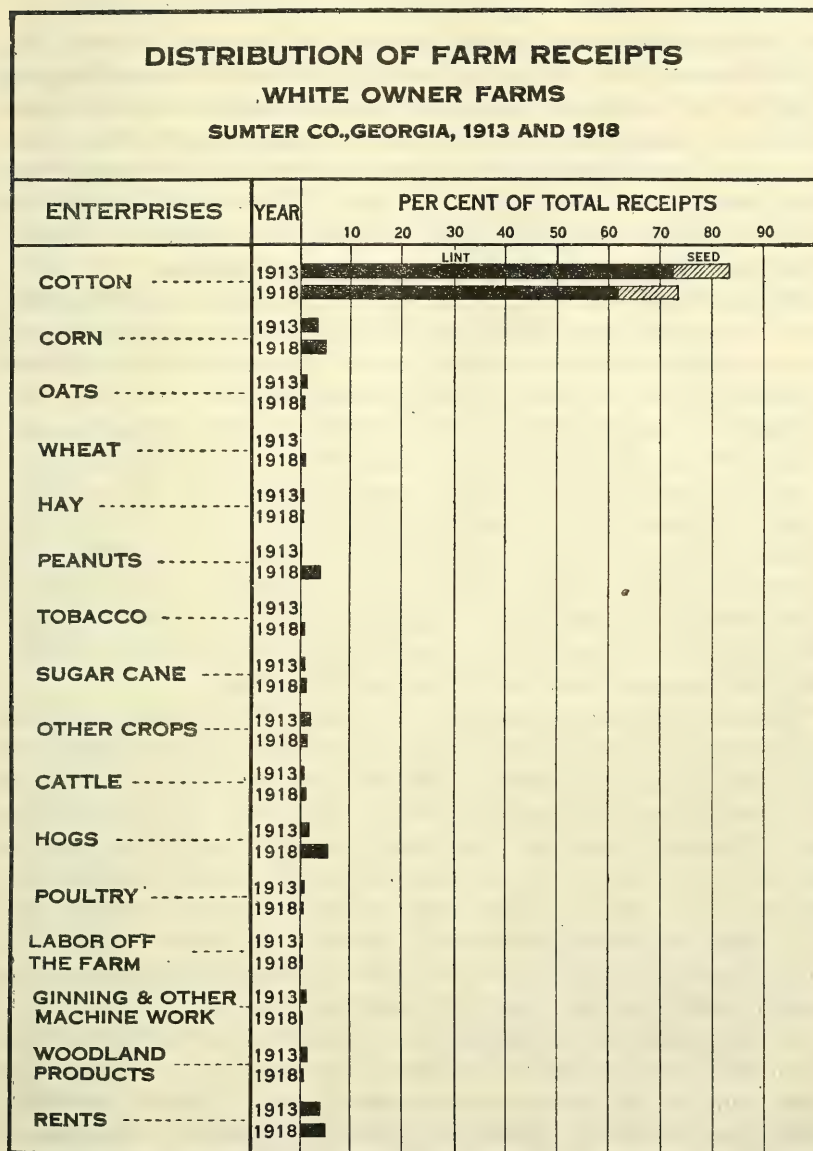


FIG. 4.—This chart brings out the importance of the cotton crop as a source of income to the farmers of Sumter County. In 1913 over 80 per cent of the money on these farms came from sales of lint cotton and cotton seed, and in 1918 over 70 per cent. Aside from cotton, the sale of corn and income from land rented out were in 1918 the only farm receipts exceeding 2 per cent of the total, while the sales of corn, peanuts, and hogs and income from rented-out land each exceeded this percentage in 1918.

This table and chart bring out clearly the relative importance of the various farm enterprises. Comparing these data for owners and tenants it is seen that the most outstanding changes were effected on

the white-owner farms, where cotton and seed represented 83.3 per cent of the total receipts in 1913 and but 73.4 per cent in 1918. The colored farmers, both owners and tenants, showed the least change in organization for the two periods, and both white and colored tenants showed less change than white or colored owners, respectively. Considering all farms, the per cent of receipts from cotton dropped from 83 per cent in 1913 to 75 per cent in 1918. This relative decrease in receipts from the cotton enterprise has been compensated for largely by the extension of the corn, peanut, and hog enterprises.

The distribution of receipts for the two periods does not indicate clearly the actual changes that have taken place in the organization of the farms unless there is also taken into consideration the relative sizes of the enterprises for each period, as shown in Table 2, since the relative prices of these products vary, and this variation affects the percentage returns from the various enterprises. On the white-owner farms the area devoted to cotton decreased 33 per cent, but the price of cotton increased from about 12 cents per pound in 1913 to about 29 cents in 1918, and cotton seed from \$26.26 per ton to \$69.07. The price of cotton and seed increased to a greater extent than the prices of other products sold, and thus returns from cotton were relatively high, even though the amount for sale was considerably less than in 1913. More feed crops and soil fertility crops were raised.

While the increased production of corn in 1918 was accompanied by an increased production of hogs, the farmers, nevertheless, were able to sell a larger quantity of corn than before. However, corn is not promising as a commercial crop in this area, owing to the low yields obtained. Receipts from corn increased from 3 per cent in 1913 to 5 per cent in 1918 on white-owner farms and from 2.1 per cent to 4.1 per cent on white-renter farms. Colored operators devoted about the same proportion of area to corn as white operators, and increased their acreage in 1918 in nearly the same proportion, but as their yields were very low both years they had little corn to sell.

In 1913 practically no peanuts were grown for market in the area, but in 1918 they yielded 4 per cent of the receipts on white-owner farms and 3.4 per cent on white-renter farms. Colored operators, however, as previously pointed out, gave little attention to this enterprise, realizing less than 1 per cent of their receipts from this source in 1918.

The other crop sales were of very minor importance, wheat, oats, hay, sirup, sweet potatoes, watermelons, tobacco, and a few others, including fruit, nuts, and vegetables, aggregating less than 3 per cent of the total receipts for all classes of operators in 1913 and less than 4 per cent in 1918.

The receipts from live stock and live-stock products are of small but growing importance. This is especially true of hogs, which are

already well established on the white-owner farms. Hogs yielded 1.7 per cent of the total farm receipts on white-owner farms in 1913, and 5.6 per cent in 1918, thus ranking next to cotton. A cooperative hog market has been organized at Plains, a village in the western part of the county, and at various times during the year the farmers arrange sales of sufficient size to attract outside buyers.

Sales of cattle and poultry and their products increased only slightly. Prices of cattle and hay have been relatively low. Receipts from man and team labor, ginning and other machine work, and woodland products are of very little importance. Rents amounted to 4.4 per cent of the total receipts on white-owner farms in 1913 and 5.1 per cent in 1918.

DISTRIBUTION OF EXPENSES.

Farm labor is the largest expense item in the operation of these farms. The labor is performed by wage hands, share croppers, and members of the farm operator's family, besides that performed by the operator himself. Considerable additional labor also is necessary at the time of chopping and picking the cotton crop and at other periods of the year with high labor demands. The labor expense ranged from 42.8 per cent to 50.9 per cent of the total expenses in the different operator classes in 1913, and from 50.6 to 58.9 per cent in 1918. (See Table 9 and fig. 5.)

The greatest increase in labor cost was for cropper labor. This was not only because the increase in the price of cotton increased cropper wages, but also because the percentage of the crop area worked by croppers increased. The white operators' actual expense for wage hands and cotton picking and chopping was less in 1918 than in 1913. Family labor was of greatest relative importance on the colored-operator farms. The probability of an increase in the price of cotton served to increase the advantage of the share system over the wage system from the laborer's standpoint, since wages naturally lag behind an advance in prices. This condition prevailed in 1918, consequently more of the cotton was grown by share-cropper labor than by wage labor.

The expense for repairs and depreciation of machinery, buildings, fences, and terraces is of considerable importance. The type of machinery used entails a rather heavy replacement expense each year. The construction and lack of care of many of the farm buildings is such that they depreciate faster than in many other parts of the country. These items represented 5.7 per cent of the total farm expense on colored-tenant farms in 1913 to 8.8 per cent in 1918 and 11 per cent of the total farm expense each year on the white-owner farms. The actual expense for machinery and buildings was greater during the latter year for all groups of farm operators.

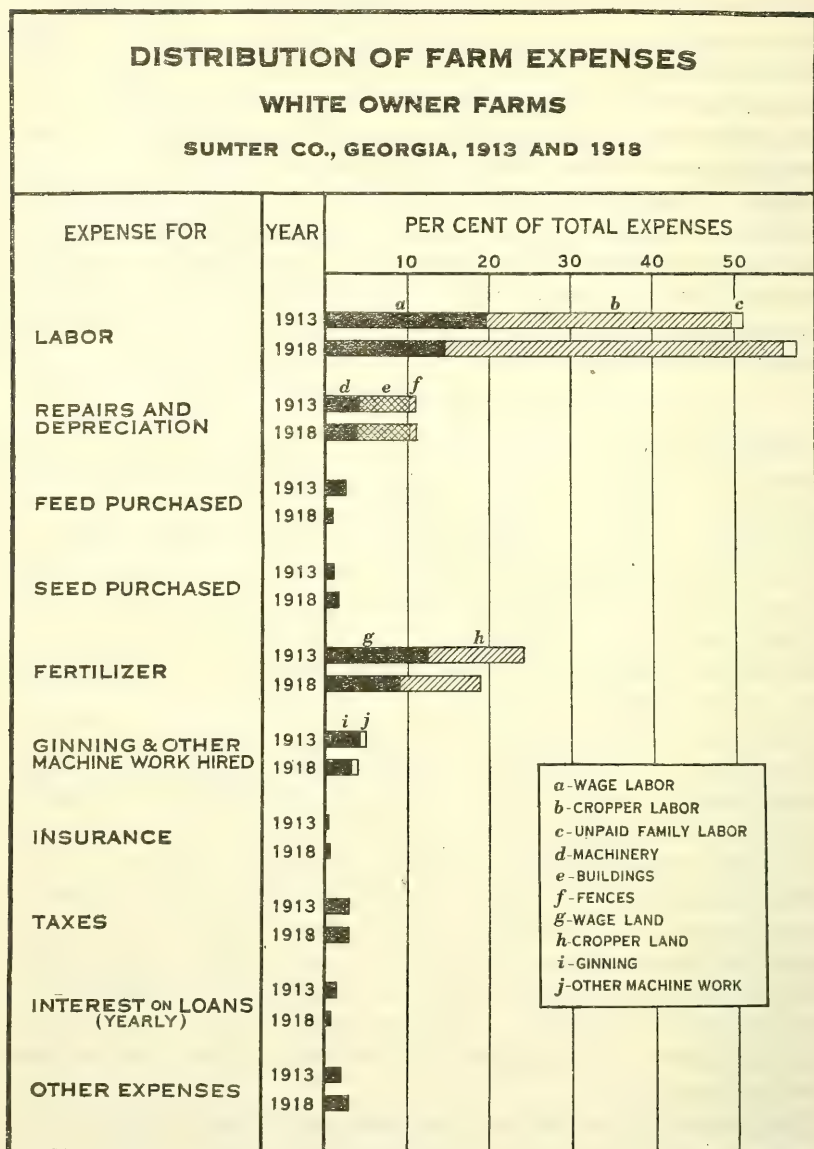


FIG. 5.—Expense for labor represented slightly over 50 per cent of the farm expenses in 1913 and almost 60 per cent in 1918. The expense for wage labor decreased from 1913 to 1918 and that for share-cropper labor increased. Fertilizer representing about 20 per cent of the farm expenses showed a percentage decrease from 1913 to 1918, and feed bought represented less than one-half as much of the farm expenses in 1918 as in 1913.

Purchased feed is not a large item of expense in this area, but it is interesting to note that it was very materially reduced in 1918, the cash outlay being less than half as great for each tenure as in 1913.

After labor, fertilizer is the largest item of expense. All groups applied a smaller quantity of fertilizer in 1918, but the increase in price increased the actual expense for 1918 over that for 1913. Cost of seed purchased is small. Most farmers through this area raise the necessary seed for farm use. Cost of ginning and other machine work ranged from 3.7 per cent to 7 per cent of the total farm expense, and taxes and insurance amounted to about 3 per cent. Miscellaneous items aggregated 2 to 3 per cent.

With these expenses offsetting from 53 to 65 per cent of total receipts, it can readily be seen that if for any reason receipts should drop 35 to 47 per cent there would be little if any left for interest on capital and for the farmer's labor and management. Production of farm feed and of home supplies in abundance is of great aid in tiding over such slumps.

TABLE 9.—Average distribution of farm expenses, Sumter County, Ga., 534 farms in 1913 and 550 in 1918.

	Owner farms.		Tenant farms.					
	1913	1918	Farm.		Tenant.		Landlord.	
			1913	1918	1913	1918	1913	1918
WHITE FARMERS.								
Number of farms	268	280	49	56	49	56	49	56
Average farm expense per farm.....	\$3, 128	\$4, 704	\$1, 099	\$1, 899	\$1, 016	\$1, 869	\$86	\$146
Per cent of farm expense represented by—								
Wage hands.....	11.9	7.9	9.1	5.2	9.8	5.2		
Cotton chopping and picking.....	6.5	3.9	8.0	5.4	8.7	5.4		
Miscellaneous paid labor.....	1.1	2.7	.4	.8	.4	.9		
Share-cropper labor.....	30.0	41.5	23.2	41.0	25.1	41.7		
Unpaid family labor.....	1.4	1.4	5.1	5.6	5.5	5.7		
Total labor.....	50.9	57.4	45.8	58.0	49.5	58.9		
Repairs and depreciation of—								
Machinery.....	4.7	4.3	3.4	3.1	3.6	3.2		
Dwelling.....	1.5	1.5	1.9	2.3			24.4	29.5
Other buildings.....	4.0	4.4	3.2	3.1			40.7	39.7
Repairs, fences, drains, and terraces.....	.6	.5	.3	.1	.2		1.2	1.4
Feed, hay, etc., purchased.....	.6	.2	1.2	.7	1.3	.7		
Feed, grain, etc., purchased.....	1.8	.5	3.5	1.2	3.8	1.3		
Horseshoeing.....	.2	.1	.2	.2	.2	.2		
Breeding fees and veterinary.....	.2	.3	.3	.2	.3	.2		
Seeds and plants.....	1.0	1.5	1.4	2.0	1.6	2.0		
Fertilizer—								
Wageland.....	12.4	9.0	18.0	10.1	19.5	10.1		1.4
Cropperland.....	11.8	10.0	8.4	6.3	9.0	6.4		
Total fertilizer.....	24.2	19.0	26.4	16.4	28.5	16.5		1.4
Ginning and other machine work hired.....	4.7	3.7	5.6	6.0	6.1	6.2		.6
Taxes and insurance.....	3.1	3.3	3.0	2.6	.7	.6	30.2	26.7
Interest on loan.....	1.3	.7	2.1	.7	2.3	.7		
Mule hire.....			.3	.2	.3	.2		
Cash rent.....					.3	6.2		
Other expenses.....	1.2	2.6	1.4	3.2	1.3	3.1	3.5	.7
Per cent of receipts required for farm expense.....	65	56	56	47	64	58	22	16

TABLE 9.—Average distribution of farm expenses, etc.—Continued.

	Owner farms.		Tenant farms.					
	1913	1918	Farm.		Tenant.		Landlord.	
			1913	1918	1913	1918	1913	1918
COLORED FARMERS.								
Number of farms.....	31	48	186	166	186	166	186	166
Average farm expense.....	\$1,259	\$1,995	\$630	\$1,070	\$599	\$999	\$34	\$86
Per cent of farm expense represented by—								
Wage hands.....	6.2	6.0	3.8	3.2	4.1	3.4		
Cotton chopping and picking.....	6.3	5.9	4.5	4.8	4.7	5.2		
Share-cropper labor.....	17.5	23.5	7.6	13.5	8.0	14.5		
Miscellaneous paid labor.....	.4	1.1	.2	.5	.2	.5		
Unpaid family labor.....	15.7	17.7	26.7	28.6	28.1	30.6		
Total labor.....	46.1	54.2	42.8	50.6	45.1	54.2		
Repairs and depreciation of—								
Machinery.....	3.5	3.0	2.8	3.8	2.9	4.0		
Dwelling.....	1.6	1.8	1.2	2.3			21.8	29.4
Other buildings.....	4.4	3.5	1.0	2.6			19.4	31.7
Repairs, fences, drains and terraces.....	.5	.3	.7	.1	.2		9.1	1.3
Feed, hay, etc., purchased.....	.8	.4	1.6	.3	1.7	.3		
Feed, grain, etc., purchased.....	3.0	1.2	4.3	1.0	4.5	1.1		
Horseshoeing.....	.2	.2	.2	.4		.4		
Breeding fees and veterinary.....	.1	.4	.1	.2	.1	.2		.1
Seeds and plants.....	.9	1.3	1.0	1.5	1.0	1.6		1.9
Fertilizer—								
Wageland.....	15.1	13.6	24.4	19.4	25.7	20.8		6.3
Cropperland.....	8.2	8.5	3.2	3.3	3.3	3.5		
Total fertilizer.....	23.3	22.1	27.6	22.7	29.0	24.3		6.3
Ginning and other machine work hired.....	7.0	5.0	6.8	7.0	7.2	7.5		.9
Taxes and insurance.....	3.4	3.4	3.4	2.9	.8	.9	49.4	27.1
Interest on loan.....	2.3	1.2	2.5	1.3	2.6	1.4		
Mule hire.....			.6	.5	.7	.6		
Cash rent.....					.5	1.5		
Other expense.....	2.9	2.0	3.4	2.8	3.5	2.0	.3	1.3
Per cent of receipts required for farm expense.....	61	53	53	41	65	54	13	11

Figure 6 emphasizes the wisdom of the changed organization in 1918 over that in operation in 1913. The chance of heavy loss is greatest in the straight cotton type of farming, since the production of this crop involves a heavy cost, which makes heavy loss certain when yields or prices, or both, are low. A loss of this kind is a very serious matter, as the farmer is forced to carry all his operating expenses for another year before income becomes available. Change in farm organization to make a reasonable income more certain each year is gaining favor throughout the area.

CAPITAL.

The capital used in operating a farm business is made up of real estate, which includes the land, buildings, and other improvements, and working capital, which includes the live stock, machinery, feed, and cash to run the farm. When the farm is operated by the owner he has the entire capital, and when operated by a tenant the tenant

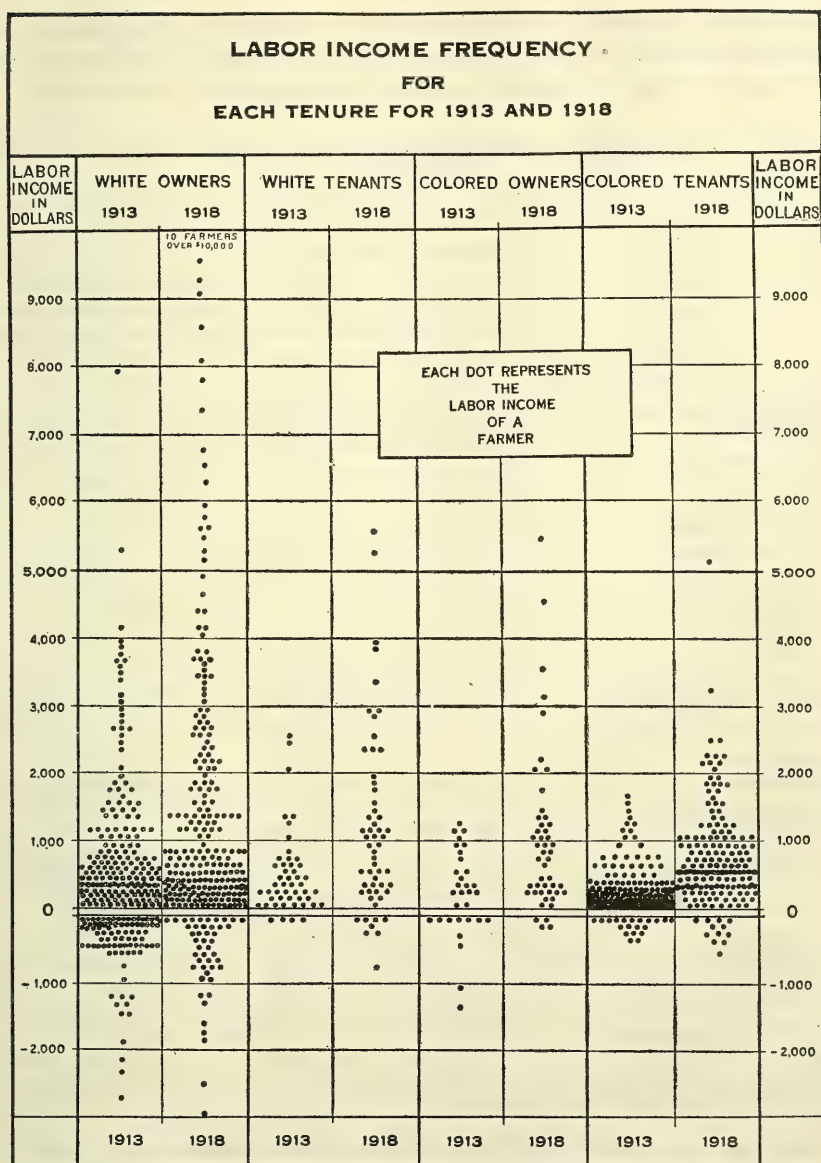


FIG. 6.—This chart shows that comparatively few of the farms returned very high labor incomes, and that the great majority of them returned less than \$1,000. With higher price levels more farms returned over \$1,000 labor incomes in 1918 than in 1913, and there were fewer farms with no labor income (those below the zero line).

owns part or all of the working capital and the landlord the real estate and sometimes part of the working capital.

Comparing the capital distribution in 1913 and 1918 (Table 10) only slight variations in percentage distribution of items appear; but the amount of capital varied greatly, with a marked increase for 1918.

Differences in size of business make wide differences in the amount of capital involved in the operation of these farms. The capital of farms of similar size showed a marked increase from 1913 to 1918.

TABLE 10.—*Distribution of capital, Sumter County, Ga., 534 farms in 1913 and 550 in 1918.*

	Owners.		Tenants.					
			Farm. ¹		Tenants.		Landlords.	
	1913	1918	1913	1918	1913	1918	1913	1918
WHITE FARMERS.								
Number of farms.....	268	280	49	56				
Capital per farm.....	\$17,020	\$27,118	\$5,642	\$9,775	\$847	\$1,738	\$4,795	\$8,037
Per cent of capital in—								
Land.....	67.9	69.4	69.4	67.8			81.7	82.4
Dwelling.....	5.8	5.8	8.0	7.5			9.4	9.2
Tenant houses.....	5.4	5.4	3.9	3.8			4.6	4.6
Other buildings.....	4.1	3.6	3.3	3.1			3.8	3.8
Total real estate.....	83.2	84.2	84.6	82.2			99.5	100.0
Work stock.....	6.6	4.7	7.6	5.9	49.1	33.0	.3	
Other live stock.....	1.0	2.0	1.3	1.9	8.9	10.6		
Machinery.....	2.3	1.8	2.3	1.7	15.2	9.7	.1	
Feed and supplies.....	4.3	4.4	3.6	5.4	22.8	30.2	.1	
Cash.....	2.6	2.9	.6	2.9	4.0	16.5		
Total working capital.....	16.8	15.8	15.4	17.8	100.0	100.0	.5	
Value of real estate per acre.....	\$34	\$53	\$34	\$50				
COLORED FARMERS.								
Number of farms.....	31	48	186	166				
Capital per farm.....	\$7,749	\$10,283	\$3,194	\$6,056	\$475	\$1,065	\$2,719	\$4,991
Per cent of capital in—								
Land.....	73.6	69.8	77.4	73.0			91.0	88.6
Dwelling.....	5.4	6.4	5.2	5.3			6.1	6.4
Tenant houses.....	3.4	4.2	.5	1.9			.5	2.3
Other buildings.....	4.2	2.6	2.0	2.1			2.4	2.6
Total real estate.....	86.6	83.0	85.1	82.3			100.0	99.9
Work stock.....	6.8	6.1	7.7	6.3	51.6	35.9		
Other live stock.....	1.1	1.9	1.4	2.2	9.0	11.9		.1
Machinery.....	1.8	1.7	1.9	1.8	13.2	10.2		
Feed and supplies.....	3.0	5.1	3.5	5.9	23.3	33.3		
Cash.....	.7	2.2	.4	1.5	2.9	8.7		
Total working capital.....	13.4	17.0	14.9	17.7	100.0	100.0		.1
Value of real estate per acre.....	\$30	\$41	\$30	\$50				

¹ Tenant's and landlord's capital combined.

RELATION OF SIZE OF FARM TO CAPITAL.

The increase in the value of these farms and equipment had an appreciable effect upon the size of business one could undertake with a given amount of capital in 1918 as compared with 1913. (See Table 11.) In 1913, there were 30 owners with less than \$3,000, and they worked an average of 38 tilled acres per farm, but in 1918 the 17 owners in this same capital class had an average of only 31 tilled acres. The owners with \$50,000 to \$100,000 in 1913 operated on the average 837 acres of tilled land, but the men in this same capital class in 1918 operated only 535 acres. Thus it was necessary for those beginning

farming in 1918 to have more capital tied up in a given sized business than would have been necessary in 1913. Similarly, the tenant with a given amount of capital could not operate as much land in 1918 as in 1913.

FARM EARNINGS.

The farm earnings for this area have been computed as follows:

1. *Farm income.*—The combined earnings for the farm capital and for the farmer's labor and management, found by deducting the farm expenses from the farm receipts.

2. *Labor income.*—The earnings of the farmer's labor and management after allowing a fair rate of interest for the use of the farm capital. The labor income for this area is found by deducting from the farm income 7 per cent interest on the capital.

3. *Per cent return on capital.*—The earnings for the farm capital after allowing for the farmer's labor and management. This is found by deducting the value of the farmer's labor and management from the farm income, and expressing the remainder as a per cent of the capital.

TABLE 11.—*Relation of size of farm to capital, Sumter County, Ga.*

Operator's capital.	White owners.				Colored tenants.			
	Number of farms.		Average number of tilled acres.		Number of farms.		Average number of tilled acres.	
	1913	1918	1913	1918	1913	1918	1913	1918
\$500 or less.....					131	33	44	38
\$501 to \$1,000.....					39	52	79	51
\$1,001 to \$2,000.....	30	17	38	31	14	66	124	91
\$2,001 to \$3,000.....					2	11	214	131
\$3,001 to \$5,000.....	37	28	69	53		4		181
\$5,001 to \$9,000.....	48	48	103	80				
\$9,001 to \$14,000.....	59	37	154	95				
\$14,001 to \$25,000.....	41	63	222	158				
\$25,001 to \$50,000.....	37	47	460	281				
\$50,001 to \$100,000.....	13	26	837	535				
Over \$100,000.....	3	14	2,052	1,152				

4. *Family income.*—The combined earnings of the farmer and of his family. This is found by deducting the farm expenses (excluding value of family labor) from the farm receipts. The family income represents the resources available to the farm family at the end of the year for living expenses, interest on indebtedness, and savings, in addition to house rent, food products, and fuel furnished by the farm.

5. *Family living from the farm.*—The value of food products, fuel, and house rent furnished directly by the farm toward the family living. This form of income is in addition to farm income, family income, and labor income.

Table 12 shows the average farm earnings of the farms in question for 1913 and 1918. The white farmers, operating larger farms and practicing the better methods of management, made the higher earnings, both per farm and per acre. The returns in 1918 were much higher than in 1913, owing primarily to higher prices of farm products. Expenses did not increase so rapidly as receipts. However, the decreased purchasing power of the dollar in 1918 as compared with 1913 made the increase in farm earnings for 1918 more apparent than real. Also, considering the cost of labor and fer-

tilizer and the yields and prices of cotton in 1920 and 1921, the earnings for these latter years must have been apparently less than in 1918.

FARM INCOME.

The farm income was more than twice as much in 1918 as in 1913. Farm income, representing the combined earnings of farm capital and the farmer's labor and management, is some indication of the size of business conducted and of the prosperity of groups of farmers. The average farm income for white-tenant farms and colored-owner farms was about one-half that for white-owner farms, and for colored-tenant farms the total farm income was only about one-third that of the farms operated by white owners. In the case of farms operated by tenants the farm income must be divided between the tenants and the landlords, the tenants in Sumter County getting about 60 per cent (ranging from an average of 55 per cent in 1913 to an average of 65 per cent in 1918) of the total farm income, and the landlords about 40 per cent. The farm income of the white tenants was about one-third and of the colored tenants about one-fifth that of the white owners.

The distribution of farms by the amount of farm income for these different classes of farms is shown in Table 13. Over 50 per cent of the white-owner farms and 90 per cent of the colored-tenant farms returned farm incomes of \$1,000 or under, and in 1918 over 50 per cent of the white-owner farms and 75 per cent of the colored-tenant farms returned farm incomes of \$2,000 or under. The average farm income for the white owners was \$1,665 in 1913, with about 25 per cent \$2,000 or over, and in 1918 the average was \$3,711, with about 25 per cent about \$4,000. About 50 per cent of them made farm incomes below \$1,000 in 1913, and about the same percentage below \$2,000 in 1918. Similar comparisons for the other groups shown in Table 13 indicate that but few farms returned high farm incomes, while many returned low farm incomes.

For both white and colored tenant farms shown in Table 13, after the total farm income is divided between tenant and landlord, the farm income of the tenant was rarely very large.

LABOR INCOME.

The labor income, representing the returns for the farmer's labor and management (after deducting 7 per cent interest for the use of the farm capital from the farm income) averaged from three to four times as much in 1918 as in 1913.

The wide variations in the labor incomes for the various farms under study in this area are shown in figure 6. This chart shows the tendency toward higher incomes in 1918.

Table 14 shows the proportion of farms falling within specified labor-income groups. In 1913 from 65 to 83 per cent of the various

groups of farms shown in the table did not return over \$500 labor income, and a number of these returned no labor income.

TABLE 12.—*Farm earnings, Sumter County, Ga., 534 farms in 1913 and 550 in 1918.*

	Owner farms.		Tenant farms.					
			Farm.		Tenant.		Landlord.	
	1913	1918	1913	1918	1913	1918	1913	1918
WHITE FARMERS.								
Number of farms.....	268	280	49	56	49	56	49	56
Farm income.....	\$1,665	\$3,711	\$872	\$2,113	\$564	\$1,353	\$308	\$759
Interest on capital, at 7 per cent.....	1,191	1,898	395	684	59	121	.....	.....
Labor income.....	474	1,813	477	1,429	505	1,232	.....	.....
Operator's labor.....	476	644	289	469	289	469	.....	.....
Per cent return on capital.....	7.0	11.3	10.3	16.9	32.5	50.9	6.4	9.4
Unpaid family labor.....	42	67	56	106	56	106	.....	.....
Family income.....	1,707	3,778	928	2,219	620	1,459	.....	.....
Interest on indebtedness.....	126	106	(¹)	(¹)	9	(²)	.....	.....
Family living from farm.....	.....	716	.....	560	.....	560	.....	.....
COLORED FARMERS.								
Number of farms.....	31	48	186	166	186	166	186	166
Farm income.....	\$805	\$1,778	\$556	\$1,546	\$323	\$843	\$233	\$703
Interest on capital, at 7 per cent.....	542	720	224	424	33	75	.....	.....
Labor income.....	263	1,058	332	1,122	290	768	.....	.....
Operator's labor.....	263	367	198	367	198	367	.....	.....
Per cent return on capital.....	7.0	13.7	11.2	19.5	26.3	44.7	8.6	14.1
Unpaid family labor.....	198	353	168	307	168	307	.....	.....
Family income.....	1,003	2,131	724	1,853	491	1,150	.....	.....
Interest on indebtedness.....	103	49	(¹)	(¹)	9	1	.....	.....
Family living from farm.....	.....	597	.....	434	.....	434	.....	.....

¹ No report on landlord's mortgages.

² Less than \$1.

(For a clear interpretation of the earnings of these groups of farms see the tables previously discussed regarding crop area, capital, yields, receipts, and expenses for these same groups.)

In 1918 the percentage of farmers making low labor incomes was decreased, there being but 36 to 45 per cent with labor incomes of \$500 or under. In 1913 less than 10 per cent of the farmers in any tenure made over \$2,000 labor income, while in 1918 26 per cent of the white owners, 21.5 per cent of the white tenants, 17 per cent of the colored owners, and 7 per cent of the colored tenants made over \$2,000 labor income. Considering all farms in 1913, 72 per cent failed to make over \$500 labor income and only 5 per cent made over \$2,000. In 1918 only 43 per cent failed to make over \$500, and 19 per cent made over \$2,000.

It should be borne in mind that in this area there are a number of farms with a very large business. There were 71 farms with over 250 acres of crops in 1913 and 76 in 1918. There were 38 farms making 100 bales or more of cotton in 1913 and 23 in 1918. Three farms were found in 1913 with over \$100,000 capital and 14 in 1918. These farms represented very large businesses and their earnings were much higher than those of smaller farms. Of 26 farmers mak-

ing over \$2,000 labor income in 1913, 19 had over 250 acres of crops, and of the 104 in 1918 43 had over 250 acres of crops. (See Tables 28 and 29 (p. 51) for the average earnings of different sized white owner and colored tenant farms.)

PER CENT RETURN ON CAPITAL.

The return on capital was over one-half more for each tenure in 1918 than in 1913. (See Table 12.)

The landlords contribute mainly capital to the farming business, and their earnings are measured by per cent returned on capital. The landlords renting to white operators had an average capital of \$4,795 per tenant in 1913, returning 6.4 per cent, and of \$8,037 per tenant in 1918, returning 9.4 per cent. Landlords renting to colored operators had an average capital of \$2,719 per tenant in 1913, returning 8.6 per cent, and of \$4,991 per tenant in 1918, returning 14.1 per cent.

TABLE 13.—*The distribution of farms by the amount of farm income, Sumter County, Ga., 534 farms in 1913 and 550 in 1918.*

Farm income.	Owner farms.		Tenant farms.					
			Total tenant farms.		Tenant's share.		Landlord's share.	
	1913	1918	1913	1918	1913	1918	1913	1918
WHITE FARMERS.								
Number of farms.....	268	280	49	56	49	56	49	56
	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
Over \$20,000.....		2.5						
\$10,001 to \$20,000.....	0.7	5.4						
\$7,501 to \$10,000.....	2.2	5.4		1.8				
\$5,001 to \$7,500.....	3.7	6.1		9.0		3.6		
\$4,001 to \$5,000.....	3.0	6.8	2.0	10.7		3.6		
\$3,001 to \$4,000.....	4.1	6.4	2.0	1.8		7.1		3.6
\$2,501 to \$3,000.....	4.5	5.4	2.0	3.6	2.0	3.6		3.6
\$2,001 to \$2,500.....	6.3	8.5	4.1	7.2	4.1	7.1		
\$1,501 to \$2,000.....	7.5	9.6	6.1	16.1	2.1	5.4		3.6
\$1,001 to \$1,500.....	17.2	13.2	14.3	16.1	6.1	21.4	2.0	8.9
\$501 to \$1,000.....	19.8	17.5	22.5	17.6	26.5	16.1	24.5	37.5
\$1 to \$500.....	28.0	12.1	47.0	16.1	53.1	23.2	73.5	41.0
\$0 to —\$500.....	3.0	1.1			6.1	7.1		1.8
—\$501 to —\$1,000.....						1.8		
COLORED FARMERS.								
Number of farms.....	31	48	186	166	186	166	186	166
	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
\$5,001 to \$7,500.....		8.3		0.6		0.6		
\$4,001 to \$5,000.....		2.1		2.4				
\$3,001 to \$4,000.....		8.3		9.1		.6		
\$2,501 to \$3,000.....	3.2	4.2	0.5	5.4		2.4		1.2
\$2,001 to \$2,500.....			.5	6.6		4.8		
\$1,501 to \$2,000.....	9.7	22.9	3.8	14.5	1.1	6.7		4.8
\$1,001 to \$1,500.....	25.8	12.5	7.0	24.7	4.8	16.9		15.1
\$501 to \$1,000.....	19.4	20.8	32.8	27.7	13.4	31.9	4.8	40.4
\$1 to \$500.....	41.9	20.9	53.8	7.8	72.6	30.1	95.2	38.5
\$0 to —\$500.....			1.6	1.2	8.1	5.4		
—\$501 to —\$1,000.....						.6		

The earnings of landlords in this region vary considerably from year to year, and almost directly as the price of cotton varies. With but very few exceptions, the landlords rented for a specified amount of lint cotton. Ordinarily the rent is based upon the number of mules necessary to operate the farm, and ranges from 2 to 3 bales per mule.

The earnings returned to landlords on many of these farms are not comparable with the earnings of landlords in the northern States. More or less supervision is given many of these tenants. The landlord in many cases gives security for tenants' credit or gives orders on stores for provisions and other supplies, settling with the tenants when the cotton is sold.

TABLE 14.—*The distribution of farms by the amount of labor income, Sumter County, Ga., 534 farms in 1913 and 550 in 1918.*

Labor income.	Per cent of total farms.											
	White-owner farms.		White-tenant farms.				Colored-owner farms.		Colored-tenant farms.			
			Farm. ¹		Tenant.				Farm. ¹		Tenant.	
	1913	1918	1913	1918	1913	1918	1913	1918	1913	1918	1913	1918
More than \$10,000.		3.6										
\$5,001 to \$10,000.	0.7	6.1				3.6		2.1		0.6		0.6
\$4,001 to \$5,000.	.4	2.1		7.2				2.1				
\$3,001 to \$4,000.	3.7	5.4		10.7		5.4		4.2		1.8		.6
\$2,501 to \$3,000.	2.6	4.3	2.0	1.8	2.0	7.1		2.1		5.4		1.2
\$2,001 to \$2,500.	1.1	4.3	4.1	7.2	4.1	5.4		6.2	0.5	7.2		4.2
\$1,501 to \$2,000.	4.1	4.3		8.9		7.1		2.1	1.1	8.5	1.1	7.2
\$1,001 to \$1,500.	7.8	8.6	4.1	14.3	8.2	19.6	12.9	20.8	5.4	20.5	4.3	13.3
\$501 to \$1,000.	14.2	16.1	24.5	19.6	20.4	16.1	19.4	16.7	14.0	32.5	11.8	33.2
\$1 to \$500.	32.5	28.9	49.0	21.4	57.1	21.4	32.3	35.4	67.2	21.7	72.0	32.5
—\$0 to —\$500.	24.6	8.9	16.3	8.9	8.2	12.5	29	8.3	11.8	1.8	10.8	6.6
—\$501 to —\$1,000.	4.1	4.6				1.8						.6
—\$1,001 to —\$1,500.	2.6	1.1					6.4					
—\$1,501 to —\$2,000.	.4	1.1										
—\$2,001 to —\$2,500.	.8											
—\$2,501 to —\$3,000.	.4	.3										
—\$3,001 to —\$4,000.		.3										
Total number of farms.	268	280	49	56	49	56	31	48	186	166	186	166

¹ Tenant's and landlord's labor income combined.

FAMILY INCOME.

The family income, as previously stated, is discussed from the standpoint of the net returns available to pay living expenses, interest on indebtedness, and provide savings. Farms with large capital may show relatively low labor incomes or low per cent return on capital, and yet, if free from debt, have relatively high incomes. From the standpoint of the operators of small farms, and especially that of most of the colored operators, many of whom have rather large families that do a large amount of the farm work, the family income is the item of most concern to the family welfare. For these reasons it is desirable to show the family income. (See Table 12.) Further data on family income are shown in Tables 30 and 31, pages 52 and 53.

The wide differences shown between family incomes and labor incomes on white-owner farms are attributable largely to the interest charge on relatively large capital and not to large amounts of family labor. The family labor on these farms amounted to only \$42 per farm in 1913 and \$67 in 1918, while where family labor was highest, on the colored-tenant farms, it averaged \$168 in 1913 and \$307 in 1918, as against labor incomes of \$290 and \$768 for the respective years.

FAMILY LIVING FROM THE FARM.

Unlike many other businesses, in farming a very significant proportion of the farmer's living comes directly from his farm. His residence is usually located on and is a part of his farm, and partly used in the operation of his business; he frequently obtains fuel in the form of wood from his farm, and usually the greater part of his food is produced on his farm. The value of all items so used may well be considered as part of the earnings of the farm business, and in many areas, especially where the farm business is comparatively small, the value of these items frequently exceeds the labor income. (See Table 15.)

TABLE 15.—*Distribution of family living from the farm, 550 farms, Sumter County, Ga., 1918.*

	White owners, (280 farms).			White tenants, (56 farms).			Colored owners, (48 farms).			Colored tenants, (166 farms.)		
Number of persons per farm over 16 years.....	3.5			3.5			4.3			4.1		
Number of persons per farm under 16 years.....	1.3			1.8			3.1			2.5		
Adult equivalent per farm.	4.4			4.8			6.4			5.8		
Items furnished by the farm for family use.	Quantity.	Value.	Per cent of value of food items.	Quantity.	Value.	Per cent of value of food items.	Quantity.	Value.	Per cent of value of food items.	Quantity.	Value.	Per cent of value of food items.
Corn, bushels.....	16	\$27	5.7	18	\$31	7.3	31	\$56	12.1	27	\$47	13.5
Wheat, bushels.....	17	39	8.2	11	24	5.7	12	30	6.5	6	14	4.0
Sirup, sugar cane and sorghum, gallons.....	23	25	5.2	18	19	4.5	32	34	7.3	21	23	6.6
Potatoes, bushels.....	30	30	6.3	26	26	6.1	34	34	7.3	27	27	7.8
Fruit and garden.....	44	9.2	.....	35	8.3	.....	36	7.8	.....	24	5	1.4
Miscellaneous.....	3	3	.....	3	3	.....	5	1.1	.....	18	5.2	.....
Butter, pounds.....	90	33	6.9	102	34	7.7	77	25	5.4	61	18	5.2
Whole milk, gallons.....	121	32	6.7	97	25	5.9	90	21	4.5	92	22	6.3
Skim milk and butter milk, gallons.....	151	16	3.3	130	15	3.5	141	16	3.5	105	12	3.5
Beef, pounds.....	5	1	(¹)	4	1	0.2	14	3	0.6	8	1	.....
Eggs, dozen.....	83	25	5.2	64	19	4.5	58	17	3.7	41	12	3.4
Poultry, head.....	56	30	6.3	41	21	5.0	34	17	3.7	24	12	3.4
Pork, pounds.....	896	172	36.0	889	171	40.3	880	169	36.5	692	131	37.7
Honey, pounds.....	2	(¹)	(²)	.....	.....	.....	2	(¹)	(²)	1	(¹)	(²)
Total food.....	.....	477	100.0	.....	424	100.0	.....	463	100.0	.....	348	100.0
Wood, cords.....	16	44	.....	13	37	.....	15	44	.....	12	35	.....
Use of house.....	.....	195	.....	.....	99	.....	.....	90	.....	.....	51	.....
Value of all items.....	.....	716	.....	.....	560	.....	.....	597	.....	.....	434	.....
Value per adult equivalent.	.....	162	.....	.....	118	.....	.....	93	.....	.....	75	.....

¹ Less than \$1.² Less than one-tenth of 1 per cent.

The average value of these items on the farms visited in this study in 1918 was equivalent to 9 per cent of the receipts on farms operated by white owners, 14 per cent on farms operated by white tenants, 16 per cent on farms operated by colored owners, and 17 per cent on farms operated by colored tenants.

Of the items of food supplied directly from the farms, pork is first in value, amounting to almost 40 per cent. Dairy products ranked second, and these two made up over 50 per cent of the value of the food supplied by the farm.

The combined value of the items of food, fuel, and house rent furnished by the farm averaged \$716 for the white-owner farms and \$560 for the white tenants, \$597 for the colored owners and \$434 for the colored tenants. The average value of these items per adult equivalent was \$162 for the white owners, \$118 for the white tenants, \$93 for the colored owners, and \$75 for the colored tenants.⁶

The value of these products on individual farms ranges from less than \$250 to over \$1,000. Table 16 shows the range in value of the family living on these farms in 1918. Only 3 per cent of the white owners and 2 per cent of the white tenants realized less than \$250 toward their family living from the farm, as against 11 per cent of the colored owners and 19 per cent of the colored tenants. Seventeen per cent of the white owners obtained over \$1,000 toward their family living direct from the farm, as against only 6 per cent of the colored owners and 2 per cent of the colored tenants.

TABLE 16.—*Percentage distribution of farms according to family living from the farm, 550 farms, Sumter County, Ga., 1918.*

Value of family living from farm.	White owners.		White tenants.		Colored owners.		Colored tenants.	
	Per cent of total number of farms.	Number of adult equivalents per farm.	Per cent of total number of farms.	Number of adult equivalents per farm.	Per cent of total number of farms.	Number of adult equivalents per farm.	Per cent of total number of farms.	Number of adult equivalents per farm.
Over \$1,000.....	17	6.3	-----	-----	6	13.0	2	6.2
\$751 to \$1,000.....	22	5.0	14	6.6	17	7.3	6	9.5
\$501 to \$750.....	34	4.2	43	5.1	35	6.7	24	6.6
\$251 to \$500.....	24	3.3	41	3.9	31	4.7	49	5.6
\$250 and less.....	3	2.0	2	2.0	11	5.0	19	3.8

About one-fourth of the white owners and two-thirds of the colored tenants got less than \$500 family living direct from the farm, while almost 40 per cent of the white owners and less than 10 per cent of the colored tenants got over \$750.

⁶ The results of studies on what the farm contributes toward the family living in several sections of the United States are published in Department Bulletin No. 410, "Value to Farm Families of Food, Fuel, and Use of House," and Farmers' Bulletin No. 1082, "Home Supplies Furnished by the Farm."

RELATION OF CAPITAL TO FARM INCOME AND LABOR INCOME.

The average-owner farm with less than \$5,000 capital in this area returns a very small farm income or labor income. (See Table 17.) Owner farms with capital of \$25,000 or more are on the average returning very good profits. The tenant beginning farming with less than \$500 capital has little chance to make more than hired man's wages, but with \$1,000 or over he makes on the average much above hired man's wages. For farmers with little capital the possibilities are much greater in renting than in owning farms.

TABLE 17.—*Relation of capital to farm income and labor income, white owners and colored tenants, Sumter County, Ga.*

Capital.	White owners.			
	Farm income.		Labor income.	
	1913	1918	1913	1918
\$500 and less.....				
\$501 to \$1,000.....				
\$1,001 to \$2,000.....	\$222	\$359	\$67	\$210
\$2,001 to \$3,000.....				
\$3,001 to \$5,000.....	464	663	193	382
\$5,001 to \$9,000.....	813	1,115	365	645
\$9,001 to \$14,000.....	1,210	1,806	417	1,035
\$14,001 to \$25,000.....	1,682	2,400	435	1,093
\$25,001 to \$50,000.....	3,265	4,636	902	2,251
\$50,001 to \$100,000.....	5,940	9,766	1,154	4,806
Over \$100,000.....	15,025	19,364	3,189	8,895

Capital.	Colored tenants.			
	Farm income.		Labor income.	
	1913	1918	1913	1918
\$500 and less.....	\$223	\$300	\$202	\$278
\$501 to \$1,000.....	498	580	449	533
\$1,001 to \$2,000.....	576	1,053	482	959
\$2,001 to \$3,000.....	1,759	1,942	1,598	1,774
\$3,001 to \$5,000.....		2,234		1,958
\$5,001 to \$9,000.....				
\$9,001 to \$15,000.....				
\$15,001 to \$25,000.....				
\$25,001 to \$50,000.....				
\$50,001 to \$100,000.....				
Over \$100,000.....				

FAMILY FARMS.

Family farms, those operated with the labor of the farmer and his family, are of such interest generally that the organization and earnings of the family farms included in this study may well be briefly discussed separately.

Usually the size of these farms are such as require from 12 to 24 months of man labor per year. Fewer acres of crops can be operated with the labor of the farmer and his family in Sumter County than in

many other areas, because the type of farming followed (cotton) is more intensive than many other types. For comparison, a group of white-owner farms in Sumter County, averaging about 73 acres of crops, required 38 months of man labor per farm; a group of dairy farms in Dane County, Wis., averaging 81 acres of crops, required 22 months, and a group of grain and live-stock farms in Clinton County, Ind., averaging 93 acres of crops, required only 19 months of labor.

Only 10 per cent of the white-owner farms in 1913 and 13 per cent in 1918 were operated as family farms, while 72 per cent of the colored-tenant farms in 1913 and 66 per cent of those in 1918 were operated as such. (See Table 18.)

TABLE 18.—*Summary of the farm business on farms operated by the farmer and his family, Sumter County, Ga.*

	White owners.		White tenants.		Colored owners.		Colored tenants.	
	1913	1918	1913	1918	1913	1918	1913	1918
Number of family farms.....	26	36	18	16	8	22	134	110
Per cent of total farms.....	10	13	37	29	26	46	72	66
Average number in family.....	5	5	5	6	7	7	6	7
Number in family under 16 years.....	2	2	2	2	3	3	3	3
In crops..... acres.....	34	37	37	49	63	61	47	53
In cotton..... do.....	15	11	22	17	39	28	30	27
In corn..... do.....	14	17	12	24	18	25	13	20
In other crops..... do.....	5	9	3	8	6	8	4	6
Cotton per acre..... pounds, lint.....	258	176	187	164	182	149	198	178
Corn per acre..... bushels.....	11	11	9	10	8	9	8	10
Months of family labor.....	8	7	6	5	15	17	13	14
Number of work stock.....	1.6	1.7	1.8	1.6	2.2	2.5	1.6	1.9
Capital per farm.....	\$3,055	\$4,117	\$416	\$978	\$3,268	\$4,759	\$518	\$755
Real estate.....	2,484	3,241			2,704	3,763		
Working capital.....	571	876	416	978	564	996	518	755
Receipts per farm.....	663	1,055	506	897	1,091	1,596	678	1,204
Expenses per farm.....	404	507	335	489	566	795	441	660
Farm income.....	259	548	171	408	525	801	237	544
Labor income.....	45	260	142	340	296	468	212	491
Unpaid family labor.....	117	145	86	109	203	340	160	280
Family income.....	376	693	257	517	728	1,141	397	824
Interest on indebtedness.....	5	3	8		45	10	8	1
Family living from farm.....		514		523		485		392
Number of farms mortgaged.....	4	2	6		5	3	50	3
Cost of cotton per pound..... lint.....	\$0.154	\$0.323	\$0.133	\$0.305	\$0.106	\$0.252	\$0.116	\$0.232
Cost of cotton per acre.....	43.35	65.96	21.01	35.80	21.77	44.72	19.57	33.73

Comparing figures on organization and operation of these family farms with the other farms, the family farms do not make as good a showing. They have lower yields, lower returns, and provide less for the family living from the farm than the farms of other classes.

FARM MORTGAGES.

In 1913 37 per cent of the farms operated by white owners were mortgaged, while in 1918 the percentage had been reduced to 23, in spite of the fact that a few changes in ownership brought into the 1918 group men whose mortgages tended to offset the general reduction in indebtedness. (See Table 19.) At the same time the interest rate

decreased slightly, from 6.8 per cent in 1913 to 6.6 per cent in 1918. The interest rate averaged highest for the farms getting the smaller loans. About one-third of the colored tenants had mortgage loans in 1913 and only 2 per cent in 1918. Ninety-seven per cent had yearly loans in 1913 and 80 per cent in 1918. The yearly loan interest rate was decreased 1 per cent in 1918 under that of 1913 for the colored tenants.

Another good measure of the increased prosperity of these farmers is shown by a comparison of the amount of money borrowed for carrying on the year's business in 1913 and 1918. It has long been the custom for many farmers in this area to borrow money necessary each year to conduct the business. (See Table 20.) For example, in 1913, 60 per cent of the white owners borrowed all or part of the cash required for farm expenses, while in 1918 only 44 per cent borrowed. The colored tenants showed a similar improvement. In 1913 91 per cent borrowed all their cash and only 3 per cent did not borrow any, while in 1918 only 60 per cent borrowed all, and 22 per cent not any.

TABLE 19.—*Farm loans and interest rates on white owner and colored tenant farms, Sumter County, Ga., 1913-1918.*

WHITE OWNERS.

	1913			1918		
	150 acres and under.	Over 150 acres.	All farms.	150 acres and under.	Over 150 acres.	All farms.
Number of farms reporting mortgage loans.	52	48	100	27	38	65
Per cent of total number of farms.	33	43	37	16	33	23
Amount of loan per farm reporting.	\$1,488	\$8,795	\$4,995	\$1,848	\$10,503	\$6,908
Interest rate (per cent).	7.7	6.6	6.8	7.0	6.5	6.6
Number of farms reporting yearly loans.	84	76	160	65	58	123
Per cent of total number of farms.	54	68	60	40	50	44
Amount of loan per farm reporting.	\$309	\$1,646	\$940	\$322	\$1,927	\$1,078
Interest rate (per cent).	7.6	6.9	7.0	7.8	7.1	7.0

COLORED TENANTS.

	50 acres and under.	Over 50 acres.	All farms.	50 acres and under.	Over 50 acres.	All farms.
Number of farms reporting mortgage loans.	33	28	61	4	4	4
Per cent of total number of farms.	34	31	33	4	4	2
Amount of loan per farm reporting.	\$168	\$418	\$250	\$360	\$360	\$360
Interest rate (per cent).	10.2	10.3	10.2	9.6	9.6	9.6
Number of farms reporting yearly loans.	92	88	180	49	83	132
Per cent of total number of farms.	96	98	97	79	80	80
Amount of loan per farm reporting.	\$104	\$205	\$153	\$117	\$211	\$176
Interest rate (per cent).	10.7	10.6	10.7	10.1	9.6	9.7

TABLE 20.—Cash for operating the farm on white owner and colored tenant farms, Sumter County, Ga., 1913-1918.
WHITE OWNERS.

	1913						1918					
	150 acres and under.			Over 150 acres.			150 acres and under.			Over 150 acres.		
	Average amount per farm.	Per cent of total.	Average amount per farm.	Per cent of total.	Average amount per farm.	Per cent of total.	Average amount per farm.	Per cent of total.	Average amount per farm.	Per cent of total.	Average amount per farm.	Per cent of total.
Cash for operating farm:												
Borrowed.....	\$167	48	\$1,117	58	\$566	56	\$128	31	\$955	40	\$474	38
Furnished by operator.....	183	52	819	42	449	44	284	69	1,454	60	773	62
Total.....	350	100	1,936	100	1,015	100	412	100	2,409	100	1,247	100
Sources of cash for operating farm:												
All borrowed.....	55	35	48	43	103	39	22	13	27	23	49	18
All furnished by operator.....	73	47	35	31	108	40	98	60	59	50	157	56
Part borrowed and part furnished by operator.....	28	18	29	26	57	21	43	27	31	27	74	26

COLORED TENANTS.

	1913						1918					
	50 acres and under.			Over 50 acres.			50 acres and under.			Over 150 acres.		
	Average amount per farm.	Per cent of total.	Average amount per farm.	Per cent of total.	Average amount per farm.	Per cent of total.	Average amount per farm.	Per cent of total.	Average amount per farm.	Per cent of total.	Average amount per farm.	Per cent of total.
Cash for operating farm:												
Borrowed.....	\$100	95	\$200	90	\$148	91	\$92	67	\$169	58	\$140	60
Furnished by operator.....	5	5	23	10	14	9	46	33	120	42	92	40
Total.....	105	100	223	100	162	100	138	100	289	100	232	100
Sources of cash for operating farm:												
All borrowed.....	86	90	76	85	162	87	33	53	38	37	71	43
All furnished by operator.....	4	4	2	2	6	3	15	24	21	20	36	22
Part borrowed and part furnished by operator.....	6	6	12	13	18	10	14	23	45	43	59	35

NUMBER OF WORK STOCK AND MONTHS OF MAN LABOR.

The number of work stock on these farms was practically the same for the two periods, but in 1918 a smaller acreage of cotton was worked per mule and an increased acreage of other crops. (See Table 21.) This applies to both owner and tenant farms, although the change was more pronounced on the white-owner farms, owing to the fact that they devoted a larger proportion of the crop area to crops other than cotton, and also because they utilized a large amount of the crop area for second crops and interplanted crops, yet the full significance of the difference in work-stock and man-labor utilization on these groups of farms the yields returned should also be considered. (See Table 4.)

The number of work stock and the amount of labor required for operating a farm are two indications of the size of business. The most labor and the most work stock was used on the white-owner farms and the least on the colored-tenant farms. The wide variations in the amount of labor and work stock used under the different tenures were largely due to the difference in average crop area. Comparing 1913 and 1918, the white owners decreased the months of labor slightly, while the other groups showed an increase. The white tenants and colored owners used about one-half as much labor per farm as the white owners, and the colored tenants about one-third as much.

TABLE 21.—*Work stock and amount of labor, Sumter County, Ga., 534 farms in 1913 and 550 in 1918.*

	White owners.		White tenants.		Colored owners.		Colored tenants.	
	1913	1918	1913	1918	1913	1918	1913	1918
Number of farms.....	268	280	49	56	31	48	186	166
Acres in crops.....	179	181	85	102	107	111	59	72
Acres in cotton.....	102	69	54	45	67	53	39	38
Acres second crop.....	12	18	9	6	5	7	1	4
Acres interplanted.....	9	54	23	9	25	2	2	10
Number work stock per farm.....	6.6	6.5	2.9	3.2	3.9	4.0	2.1	2.6
Acres of cotton per mule.....	15	11	19	14	17	13	19	15
Acres of other crops per mule ¹	13	20	14	20	12	16	10	15
Total months' labor per farm.....	95	91	40	44	53	55	31	36
Total labor represented by:								
Wage labor (per cent).....	35	30	28	20	18	18	10	11
Share cropper labor (per cent).....	49	54	33	41	33	29	10	13
Total hired labor (per cent).....	84	84	61	61	51	47	20	24
Acres of cotton per man.....	13	9	16	12	15	12	15	13
Acres of other crops per man ²	11	17	12	17	10	14	8	13
Unpaid family labor (per cent).....	3	3	9	12	26	31	42	43
Farmer's labor (per cent).....	13	13	30	27	23	22	38	34
Total unpaid labor (per cent).....	16	16	39	39	49	53	80	76
Cost of hired labor per month:								
Wage labor.....	\$18	\$25	\$17	\$25	\$17	\$26	\$18	\$24
Share cropper labor.....	20	40	19	43	13	30	16	32
Value of unpaid labor per month:								
Unpaid family labor.....	\$16	\$24	\$15	\$20	\$14	\$21	\$13	\$20
Farmer's labor.....	40	54	24	39	22	31	16	31

¹ Includes acreage used for second crops but not the acreage of interplanted crops with the main crop.

² Total months of labor divided by 12.

Practically the same amount of labor was used per crop acre under each tenure but the white farmers, and especially the white owners, got higher yields than did the colored farmers.

The white farmers hired 84 per cent of their labor each year; the white tenants, 61 per cent; colored owners about 50 per cent, and the colored renters only 20 per cent.

The cost of hired labor, family labor, and the farmer's own labor increased in about the same proportions, being about 40 to 50 per cent higher in 1918 than in 1913. Cropper labor in 1918, owing to the increased price of cotton, was double the cost in 1913.

The share-croppers working under the supervision of white operators received higher returns than those working under the supervision of colored operators, owing mainly to the difference in yields.

CHOICE OF ENTERPRISES.

When conditions affecting the agriculture of a region remain stable for a long period, local agricultural practice in the long run tends to become approximately what it should be to insure the best results, though the practice which gives the best immediate returns sometimes unfavorably affects soil fertility. When conditions change so that change in farm organization is warranted, farmers ultimately adapt their farm business to the new conditions.

In a study of the analysis of the farming business in Sumter County for the two periods 1913 and 1918 we have seen that farmers have been confronted with conditions that have made necessary some change in farm organization and farm practice, though not in type of farming, since cotton is still the leading enterprise of the area, and from all indications undoubtedly will continue to be. While the other enterprises which the farmers were stressing more in 1918 than 1913 may be distinctly profitable when occupying a minor position in the business, there is likelihood of their becoming distinctly unprofitable if made major enterprises on many farms. In this connection it is of interest to consider data regarding production per farm, prices, and diversity.

PRODUCTION PER FARM.

While it is important that a farm business be so organized as to contribute directly to the farmer's living, a farm can not be considered profitable until it is yielding enough products for sale to maintain itself adequately as a business organization. By this is meant that farm receipts must be sufficient not only to cover the yearly cash outlay, but to pay for the labor and supervision of the farmer and members of his family, as well as interest on capital.

Table 22 shows wide differences existing among the different classes of farmers in Sumter County in production per farm, owing

to differences in method of operation, size of business conducted, and yields. In 1913 the farms operated by white owners averaged 57 bales of cotton, as compared with 26 bales for the farms operated by colored owners, 25 bales for the farms operated by white tenants, and 16 bales for those operated by colored tenants. Of the 25 bales produced on the white-tenant farms, the tenant received 18 bales and the landlord 7; and of the 16 bales produced on the colored-tenant farms the tenant received 12 and the landlord 4.

TABLE 22.—*Amount of products sold per farm on white and colored owner and tenants farms, Sumter County, Ga., 1913 and 1918.*

	White owner farms.	White-tenant farms.		Colored owner farms.	Colored-tenant farms.	
		Tenant.	Landlord.		Tenant.	Landlord.
1913.						
Amount sold:						
Cotton.....bales..	57	18	7	26	12	4
Cotton seed.....tons..	20	10	(1)	8	6	(1)
Corn.....bushels..	142	38	1	40	6	(1)
Oats.....do.....	54	15	(1)			
Wheat.....do.....	(1)	(1)				
Rye.....do.....	1					
Cowpea seed.....do.....	2			2	1	
Hay.....tons..	1	1		(1)	(1)	
Peanuts.....do.....	(1)	(1)		(1)	(1)	
Sirup.....gallons..	46	15		10	5	
Sweet potatoes.....bushels..	12	6		3	3	
Cattle.....number..	1	1		1	(1)	
Hogs.....do.....	4	2		(1)		
Cured pork.....pounds..	163	25				
1918.						
Amount sold:						
Cotton.....bales..	36	14	5	20	9	5
Cotton seed.....tons..	14	8	(1)	8	6	(1)
Corn.....bushels..	287	22	5	42	17	3
Oats.....do.....	28	4		(1)	(1)	
Wheat.....do.....	28	6		1	(1)	
Rye.....do.....	2					
Cowpea seed.....do.....	5	3		10	2	(1)
Hay.....tons..	2	1		(1)	(1)	(1)
Peanuts.....do.....	3	1		(1)	(1)	(1)
Sirup.....gallons..	63	13	(1)	13	5	
Sweet potatoes.....bushels..	21	9	(1)	4	4	
Cattle.....number..	2	2		1	(1)	
Hogs.....do.....	9	4		2	1	
Cured pork.....pounds..	850	230		117	52	6

¹ Less than one-half a unit.

This table emphasizes the changes in the farm organization for the two years. Cotton and oats were the crops with a decrease in acreage in 1918 over 1913. In 1918 there was increased production of corn, wheat, cowpea seed, peanuts, sweet potatoes, cattle, and hogs, especially on the farms operated by white owners. It would seem that the change in production that has taken place, by virtue of which the farms have become more self-sustaining, not only as to food and feed production, but as to soil fertility maintenance as well, is an important improvement in the business management of these farms.

SELLING PRICES.

The prices received for farm products have an important bearing upon the farm earnings. (See Table 23.) The prices received by the

different classes of farmers are fairly constant, but the prices of different commodities show wide variation. Cotton and cotton seed were over 100 per cent higher in 1918 than in 1913, while prices of corn, oats, cowpeas, and hogs increased considerably less.

TABLE 23.—Average prices received for products sold, Sumter County, Ga., 534 farms in 1913 and 550 in 1918.

		White owner farms.	White-tenant farms.		Colored owner farms.	Colored-tenant farms.	
			Tenant.	Landlord.		Tenant.	Landlord.
1913.							
Selling price:							
Cotton.....	per pound.....	\$0.123	\$0.123	\$0.123	\$0.119	\$0.120	\$0.120
Cotton seed.....	per ton.....	26.25	23.93		23.09	21.37	
Corn.....	per bushel.....	.94	.96		.98	.95	
Oats.....	do.....	.70	.78				
Wheat.....	do.....						
Rye.....	do.....	2.64					
Cowpea seed.....	do.....	2.23			1.56	1.81	
Hay.....	per ton.....	19.70	19.00				
Peanuts.....	do.....						
Sirup.....	per gallon.....	.52	.51		.53	.54	
Sweet potatoes.....	per bushel.....	.92	1.12		.99	.95	
1918.							
Selling price:							
Cotton.....	per pound.....	.293	.288	.290	.285	.288	.291
Cotton seed.....	per ton.....	69.07	67.98		65.87	66.35	
Corn.....	per bushel.....	1.44	1.38		1.43	1.33	
Oats.....	do.....	1.11	1.31				
Wheat.....	do.....	2.27	2.58		2.28		
Rye.....	do.....	2.28					
Cowpea seed.....	do.....	2.11	2.54		2.25	2.19	
Hay.....	per ton.....	25.87	27.06				
Peanuts.....	do.....	99.48	102.99				
Sirup.....	per gallon.....	1.11	1.11		1.11	1.15	
Sweet potatoes.....	per bushel.....	1.02	1.16		1.34	1.01	

TABLE 24.—Average farm prices in Georgia, 1911-1920.¹

[Data from Bureau of Crop Estimates.]

	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920
Cotton.....pound.....	\$0.102	\$0.118	\$0.128	\$0.078	\$0.115	\$0.192	\$0.290	\$0.290	\$0.374	\$0.169
Cotton seed.....ton.....	18.18	22.11	25.16	21.45	37.68	57.09	69.38	67.88	73.71	26.50
Corn.....bushel.....	.93	.92	.95	.93	.90	1.32	1.80	1.77	1.94	1.33
Oats.....do.....	.71	.65	.66	.70	.67	.86	1.12	1.10	1.21	1.08
Wheat.....do.....	1.20	1.21	1.20	1.33	1.28	2.02	2.66	2.51	2.66	2.52
Rye.....do.....	1.41	1.37	1.18	1.15	1.18	1.47	2.16	2.06	2.27	2.21
Cowpeas.....do.....						2.02	2.34	2.50	3.78	2.27
Hay.....ton.....	19.13	18.28	17.23	17.25	16.01	17.60	20.92	25.79	29.72	23.83
Peanuts.....pound.....	.056	.055	.056	.054	.052	.062	.078	.070	.105	.054
Sweet potatoes.....bushel.....	.95	.80	.86	.84	.74	1.05	1.26	1.40	1.47	1.10
Hogs.....hundredweight.....	6.52	6.94	7.75	7.41	7.16	9.42	14.67	15.02	13.36	10.42
Beef cattle.....hundredweight.....	3.62	3.83	4.38	4.41	4.31	5.57	7.22	7.59	7.10	5.28

¹ The price for each year is the average monthly price from September of one year to August of the following year.

The data in Table 24 and figure 7, giving the average farm prices in Georgia of some of the more important farm products for the period 1911 to 1920, show that prices in 1913 were typical of normal conditions for the period 1911 to 1915, while prices in 1918 were typical of the period 1916 to 1920. In 1919 prices were highest, and all

prices show a decided decline for 1920. The year 1914 brought disastrous prices for cotton, although, considering the increase in cost of production, it is probable that 1920 was about as bad. Cotton shows the widest range in price, from 7.8 cents per pound in 1914 to 37.4 cents in 1919. The price of cattle was very low over the entire period, averaging only \$4.13 hundredweight for the period 1911 to 1915, and \$6.55 per hundredweight for the period 1915 to 1920.

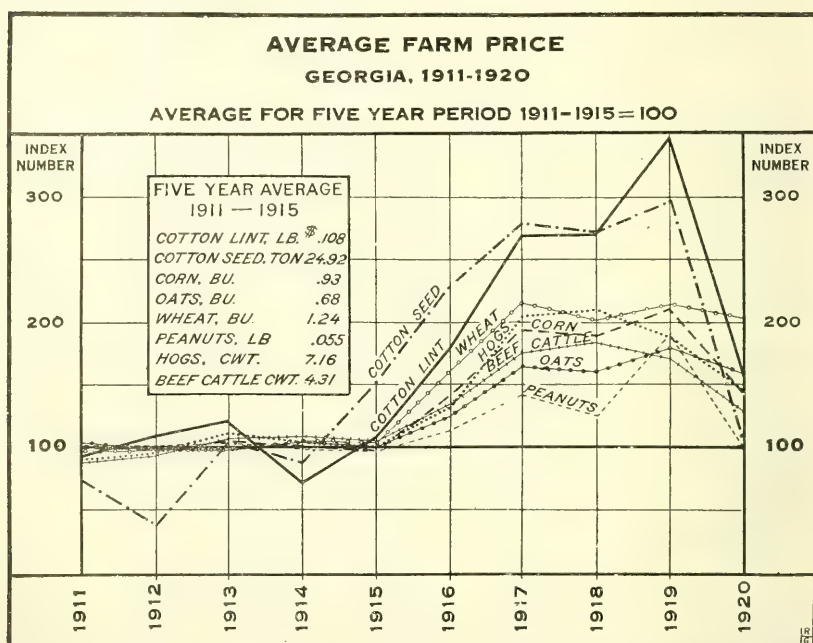


FIG. 7.—The farm prices of cotton and cotton seed varied somewhat during the period 1911 to 1915, while those of the other products were rather uniform. The prices of most products were highest in 1919, with decided declines in 1920. Cotton and cotton seed reached relatively higher prices than the other products.

DIVERSITY.

Cotton is the major enterprise in Sumter County, but there was more or less diversity of crops even in 1913, though, as already pointed out, there was greater tendency to crop diversification in 1918 than in 1913.

Perhaps the first consideration in a discussion of diversity in the organization of these cotton farms should be the growing of products for family use, for supplying feed for the work stock, and rations for the large amount of labor necessary in the operation of such farms. More or less of such products were grown on all the farms under study, but on many of them not enough were grown to meet all the requirements in the operation of the farm. White farmers produced more for family use, feed, and rations, than colored farmers, and all farms produced more in 1918 than in 1913.

In 1913, 32 per cent of the white farmers grew enough crops to supply practically all feed and rations required for operating their farms, while 30 per cent expended more than 5 per cent of farm expenses for these items. In 1918, 65 per cent of the white farmers grew practically all their feed and rations, and only 13 per cent had to buy these items in amounts greater than 5 per cent of their farm expenses.

Diversity may also be considered from the standpoint of percentage of crop area devoted to cotton. (See Table 25.)

TABLE 25.—Comparison of farms with low and high percentages of crop area in cotton, white-owner farms, Sumter County, Ga., 1913 and 1918.

	1913			1918		
	Per cent of crop area in cotton.			Per cent of crop area in cotton.		
	50 and under.	51 to 60.	Over 60.	30 and under.	31 to 40.	Over 40.
Number of farms.....	75	69	54	67	71	69
Acres per farm.....	243	229	405	277	286	277
Crop acres per farm.....	112	143	249	137	158	167
Per cent of crop area:						
In cotton.....	41	56	67	23	34	48
Used for legumes.....	17	17	12	58	49	36
Used for second crops.....	8	9	6	12	11	9
Used for interplanted crops.....	7	7	6	34	33	23
Yield of cotton per acre—pounds of lint.....	295	260	288	255	264	257
Per cent of receipts from:						
Cotton.....	71	84	90	60	76	82
Corn.....	5	4	2	6	6	4
Peanuts.....				8	4	1
Hogs.....	6	1	1	14	6	5
Per cent of farms with enterprises other than cotton each returning 10 per cent or more of farm receipts.....	37	12	1	79	48	23
Average number of enterprises other than cotton returning 10 per cent or more of the farm receipts.....	.5	.1	.1	1.1	.6	.2
Capital per farm.....	\$9,916	\$11,813	\$20,953	\$16,559	\$20,260	\$21,631
Value of real estate per acre.....	\$33	\$42	\$42	\$47	\$57	\$68
Farm income.....	\$914	\$1,134	\$2,704	\$1,824	\$2,683	\$3,726
Labor income.....	\$220	\$307	\$1,237	\$665	\$1,265	\$2,212
Operator's labor.....	\$443	\$383	\$550	\$555	\$625	\$598
Per cent return on capital.....	4.8	6.4	10.3	7.7	10.2	14.5
Family living from the farm.....				\$723	\$725	\$672

	1913		1918	
	Select farms with—		Select farms with—	
	Low per cent of crop area in cotton.	High per cent of crop area in cotton.	Low per cent of crop area in cotton.	High per cent of crop area in cotton.
Farms similar in crop area and yield of lint cotton with low and high percentages of the crop area in cotton. ¹				
Number of farms.....	30	30	30	30
Crop acres per farm.....	144	155	170	163
Yield of cotton—pounds of lint.....	257	254	244	259
Per cent of crop area in cotton.....	41	65	27	47
Labor income.....	\$186	\$619	\$722	\$2,125
Per cent return on capital.....	4.7	9.2	7.3	14.4

¹ To eliminate effects of size and yield in comparing farms with low and high percentages of crop area in cotton, 30 pairs of farms were selected each year. One farm in each pair had a low percentage of crop area in cotton, the other a high percentage. Each had practically the same crop acreage and the same yield of cotton per acre.

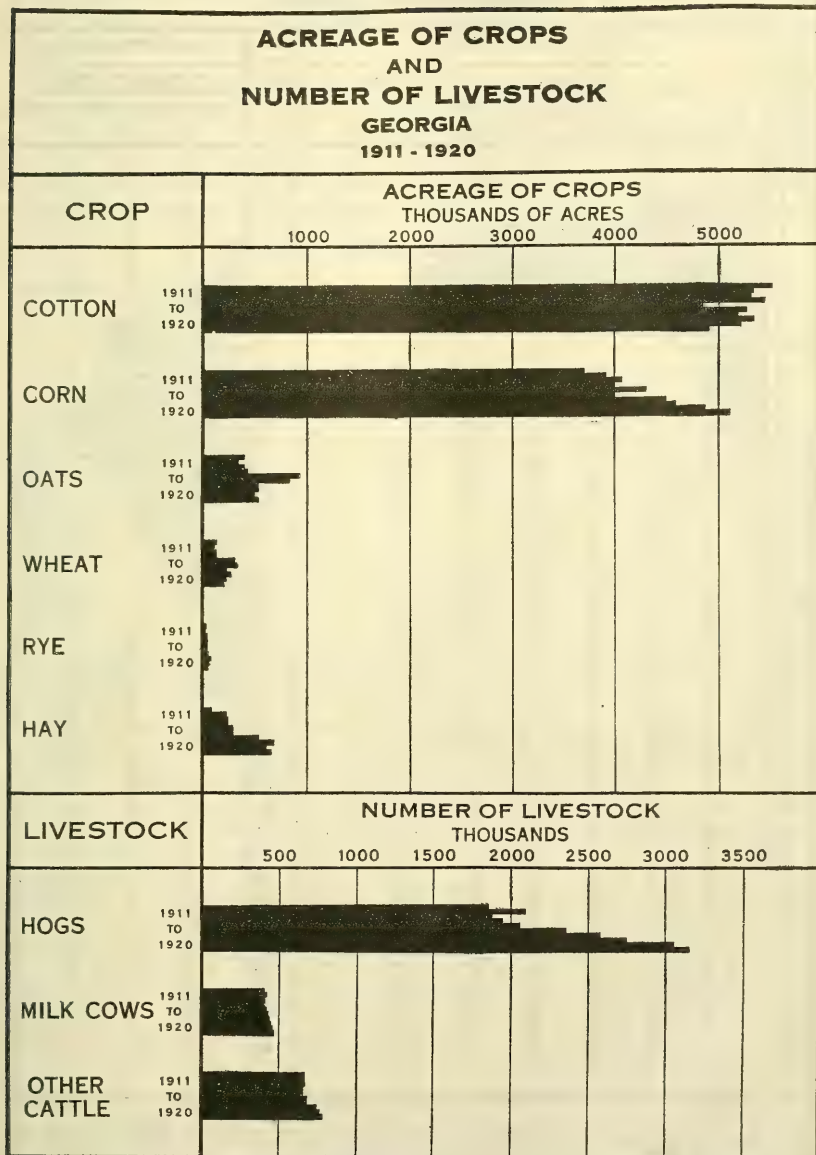
In all comparisons of farms with low and high percentages of the crop area in cotton higher earnings are indicated in favor of the farms with the higher percentages in cotton. This would seem to indicate that while other enterprises are undoubtedly profitable when occupying a minor place in the organization of these farms, in all probability they would not be as profitable as cotton if made the major sources of income. Generally speaking, the data for both 1913 and 1918 indicate that the larger proportion of crop area that can be devoted to cotton, after growing most of the feed, rations, and products for family use, the greater the farm earnings.

Diversity is sometimes indicated by the percentage of receipts derived from the various enterprises. When the farms are grouped in this respect, the indications are the same as when they are classified according to percentage of crop area in cotton. Fewer of the farms with low percentage of receipts from cotton had relatively high earnings than of the farms with high percentage of receipts from cotton. However, there seems to be a place in the agriculture of Sumter County for a few fairly highly diversified farms. Some such farms were included in this study each year, and some of these were as successful as the better cotton farms.

The character of the diversity may be indicated by the enterprises other than cotton, which returned 10 per cent or more of the farm receipts. Of the enterprises so reporting in 1913 hogs (on 8 per cent of the farms) and corn (on 5 per cent) were the leading enterprises. These were followed by oats, poultry, and outside labor, each returning over 10 per cent on 2 per cent of the farms; hay, cattle, woodlot products, and machine work on 1.5 per cent, and sweet potatoes and cane sirup each on one farm.

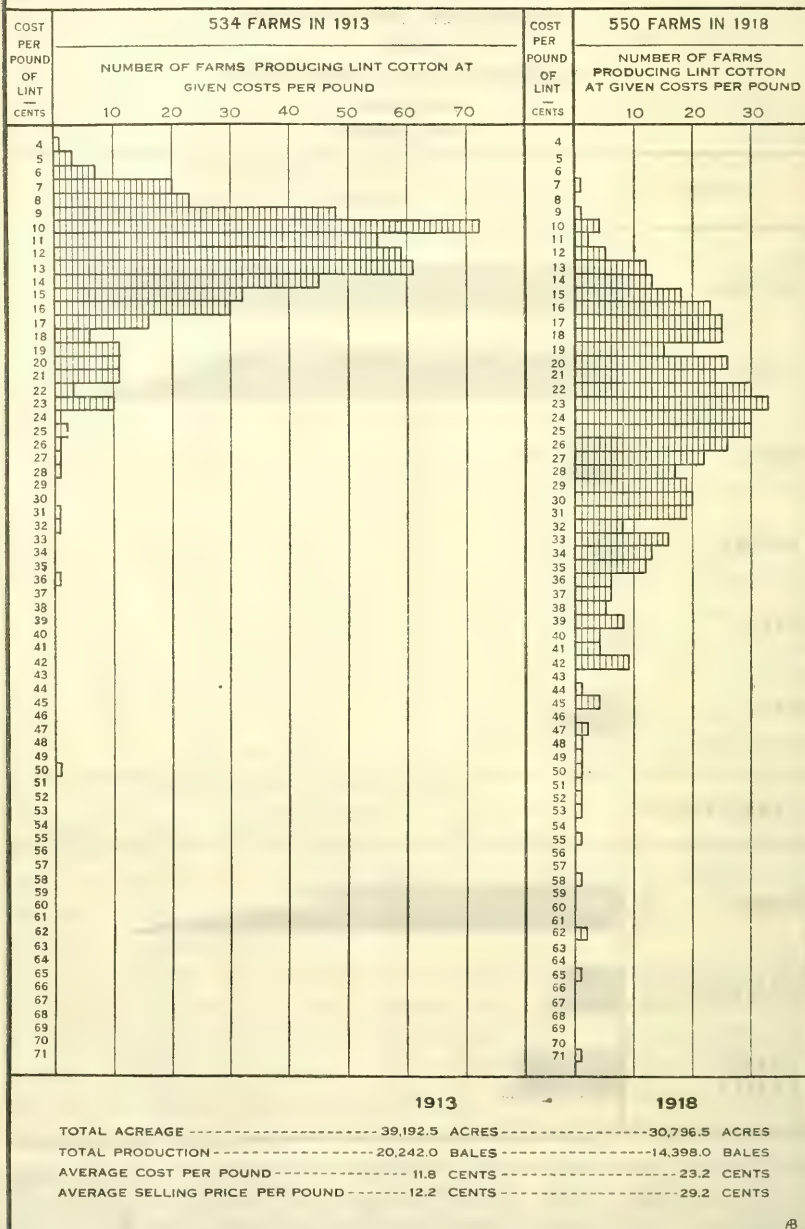
In 1918 hogs returned 10 per cent or more of the farm receipts on 33 per cent of the farms; peanuts on 17 per cent, corn on 8 per cent; outside labor, cattle, and tobacco on 2 per cent; and hay, sweet potatoes, cane sirup, truck, wheat, woodland products, and machine work each on one farm.

It is of interest in connection with a study of the changes in Sumter County toward a greater diversity of income to study also some of the changes in crop acreage and amount of live stock in the whole of Georgia for the past ten years. (See Table 26 and Plate III.) Over this 10-year period the lowest acreages in cotton were for the years 1915 and 1920. For the other eight years the cotton area shows only a slight variation from year to year. The acreage of corn shows a marked increase over the 10-year period. Oats increased to 1915, and since that time the acreage has been considerably reduced. The hay acreage has been greatly increased. Peanuts occupy about the same area as wheat, and sweet potatoes show a marked increase in acreage.



For the 10-year period 1911 to 1920 the acreage of cotton in Georgia was largest in 1911 and lowest in 1915. The tendency for the latter part of the decade was toward a reduction in cotton acreage. The acreage in corn was increased decidedly during the latter part of the 10-year period; those in oats and wheat were increased until about the middle of the period and then decreased for the latter part. Hay increased in acreage from 1911 to 1920. Hogs increased more than one-half in numbers from 1911 to 1920, while milk cows and other cattle increased but slightly.

VARIATION IN COST OF PRODUCING LINT COTTON
ON
DIFFERENT FARMS
SUMTER COUNTY, GEORGIA.



This chart illustrates the wide variation in cost of producing cotton for the different farms. In 1913 19 per cent of the farms produced at less than 10 cents per pound, 66 per cent at from 10 to 15 cents, and 15 per cent at over 15 cents. In 1918 26 per cent of the farms produced at less than 20 cents per pound, 55 per cent at from 20 to 32 cents, and 19 per cent at over 32 cents. The size of business and yield of cotton per acre largely affected such ranges in cost.

Of live stock, hogs showed by far the greatest increase, there being 1,873,000 head in the State in 1911 and 3,166,000 in 1920. Cows increased from 402,000 to 461,000, and other cattle from 667,000 to 771,000.

Table 27 shows the relation between the prices of various products in the State over the 10-year period. Prices for cotton in 1919 stood 346 per cent of the average price for 1911 to 1915, while corn stood 209 per cent, peanuts 191 per cent, and hogs 187 per cent. The prices for 1920 show large declines from those of 1919. The price of peanuts in 1920 was 2 per cent below the prewar level.

TABLE 26.—*Acreage of crops and number of live stock in Georgia, 1911-1920.*

[Expressed in thousands (000 omitted). Data from Bureau of Crop Estimates.]

	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920
Crops:¹										
Cotton.....	5,504	5,335	5,318	5,433	4,825	5,277	5,195	5,341	5,220	4,900
Corn.....	3,692	3,910	4,066	4,000	4,330	4,000	4,500	4,590	4,820	5,100
Oats.....	404	364	420	450	905	860	550	550	500	550
Wheat.....	145	132	140	140	325	334	244	280	240	211
Rye.....	12	11	13	13	13	13	15	30	33	29
Hay.....	87	234	250	250	300	300	535	696	600	660
Peanuts.....								314	202	224
Sweet potatoes..			83	79	95	94	125	130	142	148
Live stock:²										
Hogs.....	1,873	2,098	1,888	1,945	2,042	2,348	2,585	2,766	3,043	3,166
Milk cows.....	402	406	402	402	406	414	418	435	452	461
Other cattle.....	667	667	667	660	660	686	686	727	763	771

¹ Does not include all crops grown in the State; only shows the more important ones adaptable to Sumter County conditions.

² Represents number on hand Jan. 1 of each year.

TABLE 27.—*Percentage variations in farm prices in Georgia, 1911 to 1920, as compared with the five-year average, 1911-1915, taken as 100 per cent.*

[Data from Bureau of Crop Estimates. Computed from Table 24.]

	1911	1912	1913	1914	1915	1916	1917	1918	1919	1920
Cotton, lint.....	94	109	119	72	106	178	269	269	346	156
Cotton seed.....	73	89	101	86	151	229	278	272	296	106
Corn.....	100	99	102	100	97	142	194	190	209	143
Oats.....	104	96	97	103	99	126	165	162	178	159
Wheat.....	97	98	97	107	103	163	215	202	215	203
Rye.....	112	109	94	91	94	117	171	163	180	175
Hay.....	109	104	98	98	91	100	119	147	169	136
Peanuts.....	102	100	102	98	95	113	142	127	191	98
Sweet potatoes.....	113	95	102	100	88	125	150	167	175	131
Hogs.....	91	97	108	103	100	132	205	210	187	146
Beef cattle.....	88	93	106	107	104	135	175	184	172	128

The fact that only a small percentage of all the farms under study were practicing a very high degree of diversity suggests that the farmer should proceed cautiously when contemplating any very radical changes from the cotton type. Such changes should be made slowly, since they entail general economic readjustments that are essential to the success of the business. It is becoming well recognized in this area, however, that a certain degree of diversification reduces the risk of total failure, and is also an advantage in the control of the boll weevil.

When properly organized, a greater diversity of enterprises gives opportunity to use land, labor, mules, and machinery more effectively throughout the year, and the income is usually more evenly distributed than that from cotton alone, thus making it easier for the farmer to operate on a cash basis during the spring and summer months when money is needed for paying the farm expenses. Failures in individual crops are often due to conditions over which the farmer has no control, such as weather, markets, or pests. If a farmer is raising several important crops it is not likely that all will fail in any one year.

An increase in diversity also aids in the establishment of a crop rotation. A well-planned rotation, designed to improve the soil and increase yields per acre, should be the aim of all these farmers, since rotation not only increases the supply of farm feeds, but, more important still, tends to increase the production of the main money crop. For, after all, cotton is the staple crop of the region, and the general scheme of farming must be shaped with the importance of the cotton crop in view.

FACTORS AFFECTING THE SUCCESSFUL OPERATION OF THESE FARMS.

SIZE OF BUSINESS AND YIELD OF COTTON PER ACRE.

FARM EARNINGS.

To study factors that aided in increasing farm earnings, an analysis was made of the farms operated by white owners with 100 acres or under of tilled land, arranged in three groups with reference to the yield of lint cotton. (See Table 28.) Almost without exception, both in 1913 and 1918, the farm income, labor income, per cent on capital, and value of family living from the farm, increased for the various groups as the size of business increased and as the yield of cotton per acre increased. (No data were obtained on the value of family living from the farm in 1913.) The high earnings of the farms with high yields would seem to point out the shortest road to greater profits. Doubtless 25 per cent or more of these farmers could materially increase their earnings by following economical practices making for higher yields per acre.

Table 29 shows that the relation of size of farm and yield of cotton per acre to farm income, labor income, and per cent return on capital follows the same trend for the colored-tenant farms as for the white-owner farms.

A comparison of Tables 28 and 29 shows that the percentage returns on capital are larger in many instances for the tenant farms than for the owner farms. Considering the wide difference in capital involved, no conclusions can logically be drawn from these figures alone regarding the relative degree of success of these two classes of farmers. Indeed, not only the capital involved, but production per farm,

yields per acre, and various other factors must be considered in connection with such comparisons.

TABLE 28.—*Relation of size of farm and yield of cotton per acre to farm income, labor income, and per cent return on capital on white-owner farms, Sumter County, Ga., 1913-1918.*

	1913			1918			
	Farm income.	Labor income.	Per cent return on capital.	Farm income.	Labor income.	Per cent return on capital.	Family living from the farm.
100 tilled acres and under.....	\$462	\$116	4.1	\$1,064	\$549	9.1	\$558
225 pounds and less cotton per acre.....	262	7	1.4	726	321	6.5	518
225 to 300 pounds cotton per acre.....	389	22	2.7	1,304	699	10.2	603
Over 300 pounds cotton per acre.....	668	284	6.7	1,861	1,101	12.5	630
101 to 250 tilled acres.....	1,369	508	7.5	2,841	1,389	10.6	787
225 pounds and less cotton per acre.....	814	34	3.6	1,649	420	6.8	705
225 to 300 pounds cotton per acre.....	1,109	277	6.0	3,083	1,569	10.6	798
Over 300 pounds cotton per acre.....	2,016	1,074	11.1	4,037	2,378	13.8	875
Over 250 tilled acres.....	3,987	970	7.2	9,661	4,666	12.0	917
225 pounds and less cotton per acre.....	1,662	-491	3.7	7,224	2,417	9.1	849
225 to 300 pounds cotton per acre.....	3,601	766	6.9	10,264	5,153	12.6	881
Over 300 pounds cotton per acre.....	6,585	2,577	9.3	12,636	7,537	15.5	1,096
All farms.....	1,665	474	7.0	3,711	1,813	11.3	716
225 pounds and less cotton per acre.....	918	-161	3.5	2,224	751	8.2	632
225 to 300 pounds cotton per acre.....	1,248	261	6.0	4,757	2,410	12.0	758
Over 300 pounds cotton per acre.....	2,632	1,145	9.5	5,318	3,156	14.6	847

TABLE 29.—*Relation of size of farm and yield of cotton per acre to farm income, labor income, and per cent return on capital on colored tenant farms, Sumter County, Ga., 1913-1918.*

	1913			1918			
	Farm income.	Labor income.	Per cent return on capital.	Farm income.	Labor income.	Per cent return on capital.	Family living from the farm.
50 tilled acres and less.....	\$346	\$205	8.2	\$806	\$603	17.3	\$308
150 pounds and less of cotton per acre.....	215	40	1.3	549	365	9.8	286
151 to 225 pounds of cotton per acre.....	313	200	8.4	855	651	19.4	298
Over 225 pounds of cotton per acre.....	520	364	15.0	1,102	872	23.1	358
Over 50 tilled acres.....	782	470	12.7	1,986	1,431	19.9	509
150 pounds and less cotton per acre.....	325	77	4.8	1,138	668	12.5	428
151 to 225 pounds of cotton per acre.....	723	374	9.7	2,175	1,600	21.2	542
Over 225 pounds of cotton per acre.....	1,014	722	19.3	2,398	1,806	22.9	523
All farms.....	556	332	11.2	1,545	1,122	19.5	434
150 pounds and less of cotton per acre.....	253	53	2.8	862	526	11.8	262
151 to 225 pounds of cotton per acre.....	511	284	9.4	1,741	1,288	21.0	462
Over 225 pounds of cotton per acre.....	803	568	18.1	1,946	1,480	22.9	465

From these tables it may readily be seen that both size of business as measured by acres of tilled land and yield of lint cotton per acre are very important factors influencing the farm earnings in Sumter County. Obviously there is opportunity for greater earnings on large farms than on small farms, although along with opportunity for higher earnings on the large farm goes the greater risk, so that the large farm poorly organized and managed stands to incur the heavier loss when disaster comes. Within each size-group there was a group of farms returning double the yields of another group, and with much higher earnings. Thus opportunity for higher earnings through better yields per acre is quite apparent.

TABLE 30.—*Summary of the farm business, by size of farm and yield of cotton per acre, white-owner farms, Sumter County, Ga., 1913.*

Tilled area groups.....	100 acres and under.			101 to 250 acres.			Over 250 acres.		
Yield, pounds, lint cotton...	225 or less.	226 to 300.	Over 300.	225 or less.	226 to 300.	Over 300.	225 or less.	226 to 300.	Over 300.
Number of farms.....	24	39	37	20	47	36	24	17	24
Acres per farm.....	136	125	102	280	271	228	849	1,109	1,432
Per cent of farm area in—									
Pasture land.....	7	15	8	7	11	8	3	4	3
Tilled land.....	41	51	61	55	58	69	55	53	51
Tilled land rented out.....	2	4	2	4	8	6	15	15	14
Crop area per farm.....	53	58	61	143	135	144	342	420	518
Per cent of crop area in—									
Cotton.....	50	47	50	57	53	56	58	57	62
Corn.....	36	37	32	28	31	30	27	27	24
Small grains.....	6	7	10	9	9	9	10	10	10
Other crops.....	8	9	8	6	7	5	5	6	4
Used for second and inter- planted crops.....	9	12	14	12	15	13	10	13	11
Cotton per acre, pounds lint.....	188	258	371	188	266	372	178	260	337
Corn per acre..... bushels.....	10	12	14	11	13	19	12	14	20
Fertilizer, crop acre, pounds.....	277	302	422	287	323	391	326	408	499
Months of labor per farm.....	30	32	38	76	71	85	164	208	279
Number work stock per farm.....	2.1	2.4	2.6	5.1	4.9	5.8	11.1	14.2	19.7
Capital per farm.....	\$3,641	\$5,251	\$5,480	\$11,134	\$11,885	\$13,457	\$30,758	\$40,501	\$57,253
Per cent of capital in—									
<i>Real estate</i>	82	82	79	83	83	81	87	83	83
Land.....	62	64	60	69	66	61	74	71	68
Dwelling.....	13	11	10	6	9	10	4	3	4
Other buildings.....	7	7	9	8	8	10	9	9	11
<i>Working capital</i>	18	18	21	17	17	19	13	17	17
Work stock.....	6	6	7	6	6	8	6	7	7
Other live stock.....	2	2	2	1	2	1	1	1	(¹)
Machinery.....	3	3	3	3	2	3	2	2	2
Other.....	7	7	9	7	7	7	4	7	8
Value real estate per acre.....	\$22	\$34	\$43	\$33	\$36	\$48	\$31	\$30	\$33
Receipts per farm.....	\$909	\$1,164	\$1,802	\$2,732	\$3,254	\$5,056	\$6,327	\$10,681	\$17,822
Per cent of receipts from—									
Cotton and cotton seed.....	77	82	88	76	83	85	78	85	85
Corn.....	3	2	2	2	4	3	4	3	3
Other crops.....	5	6	4	7	4	5	5	3	3
Cattle and dairy products.....	3	2	1	3	1	1	1	(¹)	(¹)
Hogs.....	1	2	3	7	2	3	2	1	1
Poultry and eggs.....	2	2	1	2	1	(¹)	(¹)	(¹)	(¹)
Other.....	9	4	1	3	5	3	10	8	8
Farm expenses.....	\$647	\$775	\$1,134	\$1,918	\$2,145	\$3,040	\$4,665	\$7,080	\$11,237
Per cent expense for—									
Hired labor.....	37	32	46	43	50	53	47	52	52
Family labor.....	7	10	2	5	2	2	(¹)	(¹)	-----
Repair and depreciation:									
Machinery.....	4	4	4	4	4	3	4	4	6
Dwelling.....	4	4	3	2	2	2	1	1	1
Other buildings.....	3	4	4	4	4	3	4	4	4
Repair fence, drain, etc.....	3	1	2	1	1	1	1	1	(¹)
Feed bought.....	5	3	2	5	3	2	4	2	2
Seed bought.....	1	1	1	1	1	1	1	1	1
Fertilizer.....	26	26	26	25	22	23	26	25	24
Machine work hired.....	4	7	5	5	5	5	5	3	4
Taxes and insurance.....	4	4	3	3	3	3	4	4	3
Other.....	2	4	2	2	3	2	3	3	3
Per cent of receipts required for farm expenses.....	71	67	63	70	66	60	74	66	63
Farm income.....	\$262	\$389	\$668	\$814	\$1,109	\$2,016	\$1,662	\$3,601	\$6,585
Interest on capital at 7%.....	255	367	384	780	832	942	2,153	2,835	4,008
Labor income.....	7	22	284	34	277	1,074	-491	766	2,577
Operator's labor.....	213	246	294	418	391	524	530	808	1,241
Per cent on capital.....	1.4	2.7	6.7	3.6	6.0	11.1	3.7	6.9	9.3
Unpaid family labor.....	\$46	\$74	\$27	\$95	\$37	* \$63	\$19	\$9	-----
Family income.....	308	463	695	909	1,146	2,079	1,681	3,610	6,585
Interest on indebtedness.....	22	19	41	93	59	113	355	274	381

¹ Less than 1 per cent.

TABLE 31.—Summary of the farm business, by size of farm and yield of cotton per acre, white-owner farms, Sumter County, Ga., 1918.

Tilled area groups.....	100 acres and under.			101 to 250 acres.			Over 250 acres.		
Yield, pounds lint cotton....	225 or less.	226 to 300.	Over 300.	225 or less.	226 to 300.	Over 300.	225 or less.	226 to 300.	Over 300.
Number of farms.....	70	29	21	35	29	29	25	27	15
Acres per farm.....	107	118	123	308	267	269	1,446	1,064	1,085
Per cent of farm area in—									
Pasture land.....	14	14	8	11	14	13	11	8	7
Tilled land.....	54	58	56	53	63	60	41	56	55
Tilled land rented out.....	3	2	2	7	5	8	12	9	17
Crop area per farm.....	55	66	66	143	156	141	422	491	410
Per cent of crop area in—									
Cotton.....	35	35	31	34	40	37	31	45	35
Corn.....	43	43	41	43	36	38	33	33	39
Small grains.....	8	9	14	12	13	14	12	12	14
Other crops.....	14	13	14	11	11	11	24	10	12
Used for second and inter- planted crops.....	40	40	48	39	35	47	44	33	52
Cotton per acre, pounds lint.....	172	256	360	185	265	357	188	261	355
Corn per acre, bushel.....	12	14	15	11	14	20	14	15	17
Fertilizer, crop acre, pounds.....	147	200	175	165	219	251	227	302	319
Months of labor, per farm.....	27	35	37	64	80	82	165	257	248
Number work stock per farm.....	2.2	2.7	2.8	5.3	5.4	5.7	14.0	17.3	14.0
Capital per farm.....	\$5,780	\$8,650	\$10,858	\$17,553	\$21,626	\$23,698	\$68,664	\$73,017	\$72,849
Per cent of capital in—									
<i>Real estate.....</i>	<i>79</i>	<i>79</i>	<i>82</i>	<i>83</i>	<i>83</i>	<i>81</i>	<i>87</i>	<i>85</i>	<i>85</i>
Land.....	59	59	64	64	64	61	74	73	73
Dwelling.....	12	12	9	9	8	10	3	3	4
Other buildings.....	8	8	9	10	11	10	10	9	8
<i>Working capital.....</i>	<i>21</i>	<i>21</i>	<i>18</i>	<i>17</i>	<i>17</i>	<i>19</i>	<i>13</i>	<i>15</i>	<i>15</i>
Work stock.....	6	6	5	5	5	6	4	5	4
Other live stock.....	3	3	3	3	2	3	2	2	1
Machinery.....	3	2	2	2	2	2	2	1	2
Other.....	9	10	8	7	8	8	5	7	8
Value real estate, per acre.....	\$43	\$58	\$72	\$47	\$68	\$71	\$41	\$58	\$57
Receipts per farm.....	\$1,601	\$2,755	\$3,504	\$4,451	\$7,409	\$8,703	\$16,082	\$24,866	\$26,395
Per cent of receipts from—									
Cotton and cotton seed.....	71	73	74	69	75	75	57	82	75
Corn.....	3	4	5	5	4	4	7	4	7
Peanuts.....	5	5	4	3	5	2	10	1	2
Other crops.....	6	4	3	5	5	4	7	4	4
Cattle and dairy products.....	3	2	2	2	1	2	2	1	(1)
Hogs.....	8	8	9	9	7	10	6	3	3
Poultry and eggs.....	1	1	1	1	1	(1)	(1)	(1)	(1)
Other.....	3	3	2	6	2	3	11	5	9
Farm expenses.....	\$875	\$1,451	\$1,643	\$2,802	\$4,326	\$4,666	\$8,858	\$14,602	\$13,759
Per cent expenses for—									
Hired labor.....	39	48	53	54	59	60	52	59	59
Family labor.....	10	5	2	3	2	1	1	(1)	(1)
Repair and depreciation:									
Machinery.....	4	4	5	4	3	4	5	4	5
Dwelling.....	5	4	3	2	2	2	1	1	1
Other buildings.....	5	5	5	5	4	4	6	4	4
Repair fence, drain, etc.....	(1)	(1)	1	(1)	1	(1)	1	1	(1)
Feed bought.....	3	(1)	1	1	1	1	1	(1)	(1)
Seed bought.....	3	2	2	2	1	1	2	1	1
Fertilizer.....	19	18	14	18	16	16	20	21	20
Machine work hired.....	5	5	6	4	5	5	3	3	3
Taxes and insurance.....	4	4	3	3	3	3	4	3	3
Other.....	3	5	5	4	3	4	4	3	4
Per cent of receipts required for farm expenses.....	55	53	47	63	58	54	55	59	52
Farm income.....	\$726	\$1,304	\$1,861	\$1,649	\$3,083	\$4,037	\$7,224	\$10,264	\$12,636
Interest on capital, at 7 per cent.....	405	605	760	1,229	1,514	1,659	4,807	5,111	5,099
Labor income.....	321	699	1,101	420	1,569	2,378	2,417	5,153	7,537
Operator's labor.....	350	420	498	451	790	758	972	1,037	1,355
Per cent on capital.....	6.5	10.2	12.5	6.8	10.6	13.8	9.1	12.6	15.5
Unpaid family labor.....	\$85	\$65	\$29	\$92	\$62	\$36	\$113	\$39	\$29
Family income.....	811	1,369	1,890	1,741	3,145	4,073	7,337	10,303	12,665
Interest on indebtedness.....	9	22	17	38	44	64	478	276	277
Family living from the farm.....	518	603	630	705	798	875	849	881	1,096

¹ Less than 1 per cent.

Tables 30 and 31 are designed to permit comparisons as to organization and management of groups of small, medium, and large-sized farms, getting poor, medium, and good yields, and to show the changes in farm organization that took place in the various groups between 1913 and 1918. While it is not expedient in this discussion to analyze these tables fully, they affect certain indications as to the factors of success or failure in this area, which have an important bearing in this connection and which will be discussed briefly.

These tables show how wide is the range of possibilities for many of these farmers of increasing their earnings by following better business methods in the management of their farms. For 1913, of the farms with 100 acres or less of crops, 24 got 225 pounds or less of cotton per acre, while 37 got over 300 pounds to the acre. These 37 farms with the higher yield of cotton also had higher yields of other crops, they devoted more attention to the production of second and interplanted crops, had more and better utilized labor, better work stock, more working capital, used more fertilizer and better seed, and as a result had an average farm income of \$668 and a labor income of \$284, while the group with the poor yields and practicing the less efficient methods had an average farm income of only \$262 and a labor income of only \$7. The same comparisons may be drawn for the two groups of larger-sized farms, and the difference in results is even greater than for the group just cited, because the size of business gives a wider opportunity for success and greater risk of failure. The group of largest farms (over 250 acres of crops) with the highest yields made an average farm income of \$6,585 and a labor income of \$2,577, while the same-sized group with the lowest yields and weakest organization made a farm income of only \$1,662 and no labor income, and lacked \$491 per farm of paying for the use of capital at 7 per cent.

In 1918 nearly all these farms profited by the higher prices, since for that year the price of the products for sale had made greater advances than costs. A comparison between the returns for each group shown in Table 31 with those for the similar group in Table 30 will show a marked advance in earnings in 1918 over 1913, but that the difference in returns between well-managed farms and inefficiently managed farms was even more marked in 1918 than in 1913. Again, taking the farms with 100 acres or under in crops, we find that the farms with over 300 pounds of cotton per acre show an average farm income of \$1,861 and a labor income of \$1,101, while the same-sized group with the lowest yields (225 pounds or less) averaged in farm income only \$726 and in labor income \$321. The largest farms with the highest yields showed an average farm income of \$12,636 and a labor income of \$7,537, while the same-sized group with weak organ-

ization and low production averaged in farm income but \$7,224 and in labor income \$2,417.

SOME FACTORS THAT MAKE FOR BETTER FARM ORGANIZATION.

What are some of the more marked changes that have been made in the organization of these farms over the five-year period from 1913 to 1918?

1. About one-third reduction in cotton acreage, and about one-third increase in the much smaller corn acreage, making the acreage of each crop about equal in 1918.

2. An increase in the acreage of the small grains, this increase being almost entirely in wheat. This crop was produced on only an occasional farm in 1913, but on about two-thirds of the farms in 1918. On about 30 per cent of the farms in 1918 more wheat was grown than was required for family use, thus increasing the farm receipts by the value of the surplus.

3. An increase in the acreage of peanuts, many of which were grown for market in 1918, thus increasing the percentage of receipts from peanuts from one-tenth of 1 per cent in 1913 to 4 per cent in 1918.

4. The introduction of the velvet bean as a feed crop interplanted with corn.

5. Utilization of greater percentages of the crop land for second and interplanted crops, practically all of which were leguminous crops.

6. The growing of more feed crops, thus reducing the expense for purchased feeds.

7. Increase in the production of live stock, more particularly of hogs, thus reducing the expense for rations bought for wage hands and increasing the receipts from the sale of hogs.

8. Reduced application of fertilizer on cotton as well as other crops.

Were yields on small farms higher than on large farms?

The data show no great difference in yield of lint cotton per acre for small, medium, or large farms, being slightly in favor of the small farms in 1913 and of the large farms in 1918. Somewhat better corn yields were obtained on the larger farms each year. The wide variation of yields upon individual farms within each size group is a factor that has a vital bearing on farm earnings. In 1913 24 per cent of the small-sized farms (farms with 100 tilled acres or under) had yields of 225 pounds or less of lint cotton per acre, and 37 per cent of these small-sized farms had yields of over 300 pounds. Of the group of large-sized farms (farms of over 250 tilled acres) 37 per cent had yields of 225 pounds or less of lint cotton per acre, and another 37 per cent of these large-sized farms had yields of over 300 pounds. In 1918 58 per cent of the small-sized farms fell in the low-yield

group, while 18 per cent were in the highest-yield group; and 37 per cent of the large-sized farms were in the low-yield group and 22 per cent were in the highest-yield group.

The yield of corn, the crop next to cotton in importance, follows the same general trend as cotton in these respects, the farms with the low yields of cotton also having the low yields of corn. The yields of corn for both years were about 2 bushels per acre in favor of the large-sized farms.

Did the farmers with high yields apply more labor than those with low yields?

In both 1913 and 1918 the farms producing the high yields per acre applied more months of labor per farm than those getting the low yields. Crop acres per man and per mule were higher on the large-sized farms than on the small-sized farms, but a comparison of the man and mule labor on the low as against the high-yielding group of farms of either size shows that the farm getting the high yields per acre applied more man labor and mule labor per crop acre than those getting the low yields. In other words, the farms getting the good yields—and these are the better-organized farms—were conducting a more intensive business than those showing poor yields. Another interesting finding in this connection is that the value of labor per month and the value of mules per head were higher on the high-yielding group of farms, indicating that man labor and horse labor used on these farms is of better quality or better utilized than the labor used on the low-yielding farms.

Were the farms with good yields making heavier applications of fertilizer than those with poor yields?

Yes. In 1913 they applied over 100 pounds more per crop acre and in 1918 slightly under 100 pounds more per crop acre than the low-yield farms. Profits increase as yields are increased until the yields are considerably above the average for the region, but beyond this point increased yields are obtained at the expense of profits.

How much capital was employed per farm on the high-yielding groups of farms as compared with those groups producing the low yields?

The amount of capital per farm was uniformly higher for the high-yielding groups, and the value of real estate per acre was higher. This was mainly due to the higher percentage of the farm area under cultivation, higher yielding capacity of the land, and more and better improvements.

Did the farms with the high yields use more working capital than those with the low yields?

The farms with the good yields had much more working capital per farm, and thus were better equipped for effective operation than were the farms with the low yields.

Did the farms with the high yields grow a greater diversity of crops than those with the low yields?

With the exception of the large-size group of farms, the data show about the same percentage of the crop acreage in cotton for the farms with the high yields as for those with the low yields. However, on the farms with the high yields a greater percentage of the crop land was utilized in growing second and interplanted crops, thus effecting greater diversification without cutting down the cotton acreage. While the farmers with the high yields devoted no greater proportion of their acreage to growing crops other than cotton than the farmers with low yields, yet they had more crop acres, and with the advantage of higher yields were able to sell more of all kinds of crops and more live stock and live-stock products.

Did the farmers with high yields of cotton give less attention to growing home supplies, thus making it necessary to expend more cash for the family living than those with low yields?

No. The farmers with high yields of cotton not only sold more cotton and more products other than cotton, but they produced more for family use than those with low yields. On the high-yielding farms the family living from the farm was valued at over \$100 more per farm than on low-yielding farms of similar size, and on the large farms with high yields more than twice as much was produced for family living as on the small farms with low yields.

Did the farmers with high yields make their gains by spending less money than those with low yields or by making the money expended count for more per dollar in the operation of their business?

The data show that for each size group of farms and for both years the farmers with the good yields spent more money in the operation of their farms, often 50 per cent more per acre, than the farmers with the low yields. This difference in expense was largely for labor and fertilizer. The farmers with the good yields had relatively less expense for feed. Justification for the increased expense may be found by comparing the percentage of receipts required for expenses for the various groups of farms shown in Tables 30 and 31. The operators of the most profitable farms, small, medium, or large, having the largest business turnover and having increased their receipts in greater proportion than their expenses, received the largest returns as pay for their own labor and management and interest on capital.

Did the farmers on poorly organized farms with low earnings value their own labor as high as those on the better-organized farms with more satisfactory earnings?

No. The operators of the farms with the low yields valued their own labor and management lower than those with the high yields.

Did the operators of the small farms consider their own labor and management worth as much as did those of the large farms?

No. The farmers operating the small farms valued their own labor and management at less than half as much as did the farmers operating the large farms.

Thus it will be seen that many factors bear on the question of differences in the production and returns of these farms. On some farms an outstanding single factor was decisive, while on some others no single factor determined results. Variation in the yielding capacity of the land was no doubt a prominent factor in some instances and this influence is reflected in land values, as shown in Tables 30 and 31. There was a tendency for farms with low yields to use less working capital and expend less money in operation than those with high yields, and more of the farms with the low yields were under mortgage than of those with the high yields. These facts suggest lack of capital and possibly the need of better credit facilities on some of the farms. In a few cases age or experience of the operator appear to be the important factors affecting production and returns. An occasional farm was found with poor yields apparently due to the indifference of the operator.

In this connection it should ever be borne in mind that the capacity and efficiency of the farmer is an important factor bearing on yields and profits. Judgment as to what to do, how to do it, and when to do it is always telling in results.

The data in Tables 30 and 31 may be said to show that any given farm in this area, to be profitable, should follow the type of farming best adapted to its conditions, should be efficient in the use of both man and horse labor, adequately yet economically equipped, and as good as or better than the average farm of its type in size of business, yield of crops, and returns for live stock.

BEARING OF FARM ORGANIZATION ON COST OF PRODUCING COTTON.⁷

When a farm or an agricultural area derives the greater part of its income from a single product, the production cost per unit of the product for a given year may be determined with reasonable accuracy from the data collected through the regular farm business analysis study. An example is furnished in Sumter County, where the cotton crop occupied 59 per cent of the crop acreage and constituted 84 per cent of the farm receipts in 1913, and 42 per cent of the crop acreage and 76 per cent of the farm receipts in 1918. The crop acreage not

⁷The results of the study of cost of producing cotton on 80 of these farms was published in U. S. Department of Agriculture Bulletin No. 896. A study of the farms as compared with the average of all these farms showed them to be somewhat above the average, and this was reflected in a lower cost per pound of lint as compared with the average of the 550 farms.

occupied directly by the cotton crop was largely utilized for growing crops to support the labor and mules used in growing cotton, and thus was largely used indirectly in the production of cotton.

METHOD USED IN DETERMINING COST.

The method used in determining the cost of producing cotton involves six steps:

1. Finding the percentages of total farm receipts represented by the sale of cotton, including both lint and seed.

2. Finding the total farm expense. This is the sum of such items as labor, repairs, depreciation, feed, seed, fertilizer, insurance, taxes, etc.; the value of the farmer's own labor; and the interest on the capital in the business.

3. Calculating the farm expense chargeable to cotton, in proportion to the percentage of farm receipts derived from lint cotton and seed.

4. Finding the farm expense chargeable to lint cotton by deducting the amount received from the sale of cotton seed from the farm expense chargeable to cotton.

5. Finding the cost per acre by dividing the farm expense chargeable to cotton by the number of acres of cotton.

6. Finding the cost per pound of lint by dividing the farm expense chargeable to lint cotton by the number of pounds of lint produced.

The several steps are illustrated in Table 32.

TABLE 32.—*Illustration of method used in determining cost of producing cotton—Cost for a selected white-owner farm, Sumter County, Ga. 1918.*

Number of acres in cotton.....	63
Number of pounds of lint cotton produced.....	15, 510
Total farm receipts.....	<u>\$7, 057</u>
Receipts from sale of lint cotton.....	\$4, 560
Receipts from sale of cotton seed.....	<u>781</u>
Receipts from sale of lint and seed.....	5, 341
Per cent lint and cotton seed sales are of farm receipts.....	<u>75. 68</u>
General expenses (labor, seed, fertilizer, insurance, taxes, etc.).....	\$4, 389
Value of farmer's own labor.....	420
Interest on capital at 7 per cent.....	<u>1, 138</u>
Total farm expenses.....	5, 947
Farm expense chargeable to cotton.....	4, 501
Receipts from sale of cotton seed.....	<u>781</u>
Farm expense chargeable to lint cotton.....	3, 720
Cost per acre of cotton.....	71. 44
Cost per pound of lint.....	. 24

COST OF PRODUCTION ON DIFFERENT FARMS.

There was wide variation in the cost of production per pound of lint cotton for the different farms each year. (See Tables 33 and 34.) In 1913 (534 farms) the extreme range in cost was from 4 to 50 cents per pound, and in 1918 (550 farms) from 7 to 71 cents. A discussion

of the farms for which these extremes of cost were found for a given year is of little value, as the data show they are not typical. In any area and for any year some farms will be found ranging exceptionally high and others exceptionally low, and while figures from such farms are of interest in showing how far a few farms will vary from the mode or average, the important study is of the larger bulk of farms that have production costs within a more usual range. Tables 33 and 34 show that in 1913 10 per cent of the farms produced cotton at a cost of 8 cents or less per pound, while another 10 per cent had costs above 18 cents, leaving 80 per cent of the farms with costs ranging from 9 to 18 cents. In 1918 10 per cent of the farms produced cotton at 15 cents per pound, while 10 per cent had costs above 36 cents, leaving 80 per cent of the farms with costs ranging from 16 to 36 cents. In 1913 about two-thirds of the farms produced cotton at 13 cents or less per pound, the largest number producing at 10 cents. In 1918 two-thirds of the farms produced cotton at 27 cents or less per pound, the largest number producing at 23 cents. After eliminating the extreme farms, these tables still show a rather wide range in costs each year, and particularly for 1918.

TABLE 33.—*Variation in cost of producing lint cotton on 534 farms, Sumter County, Ga., 1913.*

Net cost per pound of lint cotton.	Farms.		Acreage.		Production.	
	Total number per group.	Cumulative per cent.	Total per group.	Cumulative per cent.	Total pounds lint per group.	Cumulative per cent.
\$0.04.....	1	0.19	47	0.12	11,880	0.12
\$0.05.....	3	.75	113	.41	36,800	.48
\$0.06.....	7	2.06	361	1.33	96,000	1.43
\$0.07.....	20	5.80	1,232	4.47	336,675	4.76
\$0.08.....	23	10.11	1,331	7.87	374,100	8.46
\$0.09.....	48	19.10	3,353	16.42	962,680	17.97
\$0.10.....	72	32.58	5,333.5	30.08	1,441,555	32.21
\$0.11.....	55	42.88	8,432	51.54	2,422,800	56.15
\$0.12.....	59	53.93	4,068	61.92	1,031,550	66.34
\$0.13.....	61	65.35	4,868.5	74.34	1,240,415	78.60
\$0.14.....	45	73.78	3,362	82.92	771,830	86.23
\$0.15.....	32	79.77	1,795	87.50	417,675	90.36
\$0.16.....	30	85.39	1,425.25	91.14	328,310	93.60
\$0.17.....	16	88.38	1,211	94.23	263,500	96.20
\$0.18.....	6	89.50	269	94.92	62,000	96.81
\$0.19.....	11	91.56	344	95.80	60,225	97.41
\$0.20.....	11	93.62	273.75	96.50	55,500	97.96
\$0.21.....	11	95.68	525	97.84	91,100	98.86
\$0.22.....	3	96.24	97	98.09	17,000	99.03
\$0.23.....	10	98.11	310	98.88	51,000	99.53
\$0.24.....	1	98.30	7	98.90	1,000	99.54
\$0.25.....	2	98.67	273	99.60	29,450	99.83
\$0.26.....	1	98.86	24	99.65	3,000	99.86
\$0.27.....	1	99.05	25	99.72	2,275	99.88
\$0.28.....	1	99.24	6	99.73	2,250	99.90
\$0.31.....	1	99.43	6.5	99.75	1,000	99.91
\$0.32.....	1	99.62	20	99.80	3,000	99.94
\$0.36.....	1	99.81	65	99.96	4,875	99.99
\$0.50.....	1	100.00	15	100.00	1,500	100.00
Total.....	534		39,192.5		10,120,945	

Average cost per pound lint..... \$0.118
 Average selling price per pound lint..... .122

TABLE 34.—*Variation in cost of producing lint cotton on 550 farms, Sumter County, Ga., 1918.*

Net cost per pound of lint cotton.	Farms.		Acreage.		Production.	
	Total per group.	Cumulative per cent.	Total per group.	Cumulative per cent.	Total pounds per group.	Cumulative per cent.
\$0.07.....	1	0.18	4	0.01	1,000	0.01
\$0.08.....	1	.18		.01		.01
\$0.09.....	1	.36	50	.17	8,000	.12
\$0.10.....	4	1.09	224	.90	47,500	.78
\$0.11.....	2	1.45	54	1.08	13,500	.97
\$0.12.....	5	2.36	443	2.52	126,680	2.73
\$0.13.....	12	4.54	630	4.57	147,450	4.78
\$0.14.....	13	6.90	430	5.97	118,455	6.43
\$0.15.....	18	10.17	1,096	9.53	259,600	10.04
\$0.16.....	23	14.35	1,446	14.23	323,560	14.53
\$0.17.....	25	18.90	1,335	18.56	356,070	19.48
\$0.18.....	25	23.45	1,864	24.61	515,230	26.64
\$0.19.....	15	26.18	1,490	29.45	380,240	31.92
\$0.20.....	26	30.91	1,825.5	35.38	464,010	38.37
\$0.21.....	24	35.27	1,925	41.63	376,345	43.60
\$0.22.....	30	40.73	1,955	47.98	501,010	50.56
\$0.23.....	33	46.73	1,421	52.59	328,620	55.13
\$0.24.....	30	52.19	1,813	58.48	497,335	62.04
\$0.25.....	30	57.65	1,849	64.48	392,370	67.49
\$0.26.....	26	62.38	1,557	69.54	416,225	73.27
\$0.27.....	22	66.38	955	72.64	202,330	76.08
\$0.28.....	17	69.47	798	75.23	183,450	78.63
\$0.29.....	19	72.93	1,442	79.91	329,845	83.21
\$0.30.....	20	76.57	937	82.95	175,840	85.65
\$0.31.....	19	80.03	1,269	87.07	277,735	89.51
\$0.32.....	8	81.48	217	87.77	50,585	90.21
\$0.33.....	16	84.39	1,010	91.05	190,935	92.86
\$0.34.....	13	86.75	555	92.85	112,435	94.42
\$0.35.....	12	88.93	546	94.62	106,465	95.90
\$0.36.....	6	90.02	229	95.36	49,550	96.59
\$0.37.....	6	91.11	286	96.29	42,750	97.18
\$0.38.....	5	92.02	172	96.85	37,315	97.70
\$0.39.....	8	93.47	123	97.25	24,030	98.03
\$0.40.....	4	94.20	68	97.47	15,520	98.25
\$0.41.....	4	94.93	97	97.78	15,850	98.47
\$0.42.....	9	96.57	320	98.82	49,100	99.15
\$0.44.....	1	96.75	46	98.97	10,750	99.30
\$0.45.....	4	97.48	107	99.32	25,310	99.65
\$0.47.....	2	97.84	28	99.41	4,000	99.71
\$0.48.....	1	98.02	25	99.49	3,850	99.76
\$0.49.....	1	98.20	4	99.50	750	99.77
\$0.50.....	1	98.38	45	99.65	3,200	99.81
\$0.51.....	1	98.56	34	99.76	2,820	99.85
\$0.52.....	1	98.74	18	99.82	4,000	99.91
\$0.53.....	1	98.92	6	99.84	750	99.92
\$0.55.....	1	99.10	3	99.85	1,000	99.93
\$0.58.....	1	99.28	15	99.90	1,735	99.95
\$0.62.....	2	99.64	14	99.95	1,640	99.97
\$0.65.....	1	99.82	7	99.97	1,250	99.99
\$0.71.....	1	100.00	9	100.00	900	100.00
Total.....	550		30,796.5		7,198,800	

Average cost per pound lint..... \$0.232
 Average selling price per pound lint..... .292

The acreage and the amount of lint that was produced are also shown in Tables 33 and 34. A larger percentage of the total production than of either farms or acreage falls in the low-cost groups. In 1913 over three-fourths of the cotton was produced at 13 cents or less per pound, and in 1918 three-fourths was produced at 27 cents or less per pound. The acreages with the higher yields more generally fall in the lower cost groups.

In 1913 the average cost was 11.8 cents per pound, and about 52 per cent of the farms produced at this cost or less. This average cost included about 60 per cent of the acreage and about 64 per cent of the production. In 1918 the average cost was 23.2 cents per pound, and this included 48 per cent of the farms, 54 per cent of the acreage, and 57 per cent of the production.

In 1913 the cost of production was above the average on 48 per cent of the farms, and included about 40 per cent of the acreage and about 36 per cent of the production, while in 1918 the cost of production was above the average on 52 per cent of the farms, and included 46 per cent of the acreage and 43 per cent of the production.

The average price received in 1913 was 12.2 cents and the average cost of production 11.8 cents. In 1918 the average price received was 29.2 cents and the average cost 23.2 cents.

Plate IV shows the number of farms producing at various costs in 1913 and 1918.

COST OF PRODUCTION BY CLASSES OF FARMERS.

Table 35 shows a range in average cost in 1913 from 10.3 cents per pound of lint for white tenants to 12.2 cents per pound for white owners. In 1918 the range was from 20 cents per pound for the white tenants to 24.6 cents for white owners.

The cost to the white-owner operators is the one of most importance in cotton production in this area. The white owners represented one-half the farms under study for each year, but in 1913 they had 72 per cent of the cotton acreage and 75 per cent of the cotton production, and in 1918, 69 per cent of the cotton acreage and 69 per cent of the cotton production.

While their cost per unit of production was higher in both 1913 and 1918 than for either white tenants, colored owners, or colored tenants, the size of their business and greater efficiency of operation won for them the largest farm incomes and labor incomes. (See Table 12, page 33.)

The average cost in 1918 for each class of operators shown in the table was slightly less than twice that of 1913 except for the white owners, whose average cost in 1918 was slightly more than twice that of 1913.

On most of the tenant farms, owing to the small size of business conducted and small output per worker, the cost must of necessity be comparatively low per unit of production if they are to have left a living income after paying rent and other expenses. The owner farms, on the other hand, are equipped for a much larger output per man; they have better buildings, machinery, mules and other working equipment, which increase their cost per unit of production,

but more than offset such increase by making for increased production per man. Future changes in the organization and operation of these tenant farms for greater efficiency and larger returns must undoubtedly be accomplished along similar lines.

The interpretation of these cost data for owners and tenants, white and colored, without the aid of the data regarding size of business, distribution of crop area, yields, production per farm, and returns, shown elsewhere in this bulletin, might lead to erroneous conclusions.

SIZE OF FARM AND YIELD OF COTTON PER ACRE AS FACTORS AFFECTING COST OF PRODUCTION.

One of the objects in showing cost of production data, along with an analysis of the organization of these various farms and groups of farms, was to set forth the fact that the fundamental principles underlying efficiency in cost of production of a given crop are the same as those bearing on the successful conduct of the farm as a whole. Reduced costs of production and increased profits are obtained through the efficient organization and operation of the business. To set forth clearly the relation between good farm organization and efficient operation in reducing the cost of producing cotton, Table 36 is given. The same grouping of farms was used in this table as in Tables 30 and 31, in which the organization of each group is rather clearly portrayed and the profits shown. The effect of size of farm upon cost of production is shown for the different size-groups having similar yields per acre. The effect of yield per acre may also be studied by comparing the groups of farms with different yields per acre but of similar size.

TABLE 35.—*Cost of producing cotton, Sumter County, Ga., 534 farms in 1913 and 550 in 1918.*

	White-owner farms.		White-tenant farms.				Colored-owner farms.		Colored-tenant farms.			
			Farm basis.		Renter basis.				Farm basis.		Renter basis.	
	1913	1918	1913	1918	1913	1918	1913	1918	1913	1918	1913	1918
Number of farms.....	268	280	49	56	49	56	31	48	186	166	186	166
Acres tilled per farm.....	227	224	85	108	85	108	145	125	59	73	59	73
Acres in cotton per farm....	102	69	54	45	54	45	67	53	39	38	39	38
Per cent of crop acreage in cotton.....	57	38	63	45	63	45	62	48	66	52	66	52
Yield per acre (pounds of lint cotton).....	279	257	227	211	227	211	192	189	211	191	211	191
Cost per acre.....	\$39.04	\$76.95	\$29.38	\$55.55	\$21.84	\$42.49	\$25.18	\$51.61	\$25.57	\$46.81	\$19.82	\$35.43
Cost per pound lint cotton..	\$0.122	\$0.246	\$0.11	\$0.206	\$0.103	\$0.200	\$0.118	\$0.223	\$0.105	\$0.192	\$0.106	\$0.209

NOTE.—See Table 12, p. 33, for the incomes of these same groups of farms.

TABLE 36.—*Relation of size of farm and yield of cotton per acre to cost of producing cotton per acre and per pound of lint, white-owner farms, Sumter County, Ga., 1913 and 1918.*

Size of farm (tilled area).	Cost per pound of lint cotton.				Cost per acre.			
	Yield-per-acre groups.				Yield-per-acre groups.			
	225 pounds or less, low yields.	226 to 300 pounds, medium yields.	Over 300 pounds, high yields.	All yields.	225 pounds or less, low yields.	226 to 300 pounds, medium yields.	Over 300 pounds, high yields.	All yields.
1913. ¹								
100 acres or under (small farms).....	\$0. 155	\$0. 144	\$0. 123	\$0. 135	\$32. 09	\$40. 86	\$52. 02	\$43. 35
101 to 250 acres (medium farms).....	. 144	. 128	. 111	. 122	29. 34	38. 73	47. 92	40. 20
Over 250 acres (large farms).....	. 141	. 124	. 110	. 119	28. 65	37. 51	43. 46	37. 74
All sizes.....	. 144	. 128	. 112	. 122	29. 12	38. 41	45. 39	39. 04
1918. ²								
100 acres or under (small farms).....	. 297	. 252	. 238	. 267	59. 86	78. 27	103. 99	72. 64
101 to 250 acres (medium farms).....	. 291	. 255	. 224	. 251	62. 99	81. 51	99. 67	80. 74
Over 250 acres (good farms).....	. 274	. 238	. 216	. 240	62. 23	76. 33	96. 62	76. 24
All sizes.....	. 283	. 243	. 221	. 246	61. 94	77. 56	98. 43	76. 95

¹ See Table 30 for the business analysis of these same groups of farms.² See Table 31 for the business analysis of these same groups of farms.

The larger farms of any given class or tenure produced cotton on the average at lower costs per pound of lint than the smaller farms, both in 1913 and 1918, and the high-yielding groups of any given size produced cotton at a much lower cost than the low-yielding groups. In illustration of the effect of size of farm upon cost of production per pound of lint cotton, the farms with low yields (225 pounds or less of lint cotton per acre) may be compared. The cost per pound of lint cotton on the small farms (farms of 100 acres or less) in 1913 was 15.5 cents and on the large farms (those of over 250 acres) 14.1 cents, while in 1918 the cost on the small farms was 29.7 cents and on the large farms 27.4 cents. The cost on the large farms with low yields was 1.4 cents less per pound of lint cotton than on the small farms with similar yields per acre in 1913, and 2.3 cents less in 1918.

Such comparisons for the groups with medium and with high yields per acre also show that the large farms produced at a lower cost per pound of lint cotton than the small farms. Summarizing, the large farms in the respective yield-per-acre groups are shown to have produced at 1.4 cents, 2.0 cents, and 1.3 cents per pound less than the small farms in 1913, and at 2.3 cents, 1.4 cents, and 2.2 cents less in 1918, averaging 1.6 cents less in 1913 and 2.7 cents less in 1918.

In illustration of the effect of low, medium, and high yields per acre upon the cost of production per pound of lint cotton, the small farms (those of 100 acres or less) may be compared. The cost of production per pound of lint on the farms with low yields per acre (225 pounds or less of lint cotton) in 1913 was 15.5 cents, and on the

farms with high yields per acre (over 300 pounds of lint cotton) 12.3 cents, while in 1918 the cost on the farms with low yields was 29.7 cents and on the farms with high yields 23.8 cents per pound. The average cost on the farms with high yields per acre was 3.2 cents less per pound of lint than on those of similar size but with low yields per acre, in 1913, and 5.9 cents less in 1918.

Such comparisons for the groups of medium and large-sized farms also show the group with high yields producing at the lower costs per pound of lint cotton. Summarizing, the group of farms obtaining the high yields per acre are shown to have produced cotton at an average cost of 3 cents less per pound in 1913 and 6 cents less in 1918 than the farms of the low-yield group.

Comparing on cost per acre, the large farms produced cotton at a lower cost than the small farms with like yields, the difference averaging \$5.12 per acre in 1913 and \$2.31 in 1918.

A much higher cost per acre was incurred on the farms with good yields than on those with low yields, the average difference in cost between the lowest yield-per-acre group and the highest yield-per-acre group being \$17.77 per acre in 1913 and \$38.40 in 1918.

Table 37 shows the effect of size of farm and yield of lint cotton per acre upon the cost of production on farms operated by colored tenants. While the average yield per acre upon these farms was lower than upon white-owner farms, the wide variation in yields enables comparison for these farms in the same manner as upon the white-owner farms. Because the colored-tenant farms do not show so wide a range in size as the white-owner farms, they were arranged in only two size groups, those with 50 acres or under of tilled land and those with over 50 acres.

TABLE 37.—*Relation of size of farm and yield per acre to cost of producing cotton per acre and per pound of lint, colored tenant farms, Sumter County, Ga.¹*

Size of farm (tilled area).	Cost per pound of lint.				Cost per acre.			
	Yield-per-acre groups.				Yield-per-acre groups.			
	150 pounds and under. (Low yields.)	151 to 225 pounds. (Medium yields.)	Over 225 pounds. (High yields.)	All yields.	150 pounds and under. (Low yields.)	151 to 225 pounds. (Medium yields.)	Over 225 pounds. (High yields.)	All yields.
1913.								
50 acres and under...	\$0.165	\$0.115	\$0.095	\$0.115	\$23.54	\$25.22	\$32.07	\$26.73
Over 50 acres.....	.134	.108	.087	.100	19.78	24.58	27.45	25.06
All sizes.....	.149	.110	.089	.105	21.57	24.76	28.59	25.57
1918.								
50 acres and under...	.264	.203	.184	.211	38.25	47.72	62.80	47.94
Over 50 acres.....	.233	.183	.175	.188	36.45	45.38	59.26	46.54
All sizes.....	.241	.186	.177	.192	36.93	45.75	59.95	46.81

¹ See Table 29 for the incomes on these same groups of farms.

Yield per acre is the important factor in reducing cost on the tenant farms. The large-size group had a reduced cost of $1\frac{1}{2}$ cents per pound of lint over the small-size group in 1913 and 2.3 cents in 1918, but comparing the high-yield-per-acre group with the low-yield-per-acre group, the high-yield-per-acre group had an average cost of 6 cents per pound less in 1913 and 6.4 cents less in 1918.

The average acre cost for the farms with yields of over 225 pounds was \$7.02 more than those with yields of 150 pounds or less in 1913 and \$23.02 more in 1918.⁸

While the average cost per pound of lint was less for the large farms than for the small farms and for the farms with high yields than for those with low, there were wide variations within the several groups. These variations are shown in the frequency classification of white-owner farms for both 1913 and 1918.

Frequency cost classification, white-owner farms.

In 1913:

Of the 100 farms with 100 tilled acres or under—

24 had yields of 225 pounds or less of lint.

39 had yields of 226 to 300 pounds of lint.

37 had yields over 300 pounds of lint.

Of the 24 farms having yields of 225 pounds or less of lint—

1 had a cost of 10 cents or less per pound of lint.

10 had costs from 11 to 15 cents per pound of lint.

13 had costs over 15 cents per pound of lint.

Of the 39 farms having yields of 226 to 300 pounds of lint—

6 had costs of 10 cents or less per pound of lint.

18 had costs from 11 to 15 cents per pound of lint.

15 had costs over 15 cents per pound of lint.

Of the 37 farms having yields over 300 pounds of lint—

8 had costs of 10 cents or less per pound of lint.

18 had costs from 11 to 15 cents per pound of lint.

11 had costs over 15 cents per pound of lint.

Of the 103 farms with 101 to 250 acres—

20 had yields of 225 pounds or less of lint.

47 had yields of 226 to 300 pounds of lint.

36 had yields over 300 pounds of lint.

Of the 20 farms having yields of 225 pounds or less of lint—

2 had costs of 10 cents or less per pound of lint.

11 had costs from 11 to 15 cents per pound of lint.

7 had costs over 15 cents per pound of lint.

Of the 47 farms having yields of 226 to 300 pounds of lint—

6 had costs of 10 cents or less per pound of lint.

32 had costs from 11 to 15 cents per pound of lint.

9 had costs over 15 cents per pound of lint.

Of the 36 farms having yields over 300 pounds of lint—

15 had costs of 10 cents or less per pound of lint.

17 had costs from 11 to 15 cents per pound of lint.

4 had costs over 15 cents per pound of lint.

⁸ This discussion of costs on colored-tenant farms applies to the cost for the farm, but the same findings apply to the tenant's cost of his share of cotton.

In 1913—Continued.

Of the 65 farms with over 251 acres—

24 had yields of 225 pounds or less of lint.

17 had yields of 226 to 300 pounds of lint.

24 had yields over 300 pounds of lint.

Of the 24 farms having yields of 225 pounds or less of lint—

2 had costs of 10 cents or less per pound of lint.

14 had costs from 11 to 15 cents per pound of lint.

8 had costs over 15 cents per pound of lint.

Of the 17 farms having yields of 226 to 300 pounds of lint—

2 had costs of 10 cents or less per pound of lint.

13 had costs from 11 to 15 cents per pound of lint.

2 had costs over 15 cents per pound of lint.

Of the 24 farms having yields over 300 pounds of lint—

9 had costs of 10 cents or less per pound of lint.

15 had costs from 11 to 15 cents per pound of lint.

0 had costs over 15 cents per pound of lint.

In 1918:

Of the 120 farms with 100 tilled acres or under—

70 had yields of 225 pounds or less of lint.

29 had yields of 226 to 300 pounds of lint.

21 had yields over 300 pounds of lint.

Of the 70 farms having yields of 225 pounds or less of lint—

4 had costs of 20 cents or less per pound of lint.

31 had costs from 21 to 30 cents per pound of lint.

35 had costs over 30 cents per pound of lint.

Of the 29 farms having yields of 226 to 300 pounds of lint—

5 had costs of 20 cents or less per pound of lint.

15 had costs from 21 to 30 cents per pound of lint.

9 had costs over 30 cents per pound of lint.

Of the 21 farms having yields over 300 pounds of lint—

5 had costs of 20 cents or less per pound of lint.

12 had costs from 21 to 30 cents per pound of lint.

4 had costs over 30 cents per pound of lint.

Of the 93 farms with 101 to 250 acres—

35 had yields of 225 pounds or less of lint.

29 had yields of 226 to 300 pounds of lint.

29 had yields over 300 pounds of lint.

Of the 35 farms having yields of 225 pounds or less of lint—

1 had costs of 20 cents or less per pound of lint.

20 had costs from 21 to 30 cents per pound of lint.

14 had costs over 30 cents per pound of lint.

Of the 29 farms having yields of 226 to 300 pounds of lint—

6 had costs of 20 cents or less per pound of lint.

15 had costs from 21 to 30 cents per pound of lint.

8 had costs over 30 cents per pound of lint.

Of the 29 farms having yields over 300 pounds of lint—

8 had costs of 20 cents or less per pound of lint.

18 had costs from 21 to 30 cents per pound of lint.

3 had costs over 30 cents per pound of lint.

Of the 67 farms with over 250 acres—

25 had yields of 225 pounds or less of lint.

27 had yields of 226 to 300 pounds of lint.

In 1918—Continued.

Of the 67 farms with over 250 acres—Continued.

15 had yields over 300 pounds of lint.

Of the 25 farms having yields of 225 pounds or less of lint—

4 had costs of 20 cents or less per pound of lint.

8 had costs from 21 to 30 cents per pound of lint.

13 had costs over 30 cents per pound of lint.

Of the 27 farms having yields of 226 to 300 pounds of lint—

9 had costs of 20 cents or less per pound of lint.

13 had costs from 21 to 30 cents per pound of lint.

5 had costs over 30 cents per pound of lint.

Of the 15 farms having yields over 300 pounds of lint—

6 had costs of 20 cents or less per pound of lint.

8 had costs from 21 to 30 cents per pound of lint.

1 had a cost over 30 cents per pound of lint.

DISTRIBUTION OF COSTS.

The detailed items making up the cost of producing a product may be grouped in several different ways, depending upon the way in which they are considered.

The cost of a farm product may be thought of as made up of the several operations required for producing the product. Thus, the production of cotton requires plowing, harrowing, planting, cultivating, hoeing, chopping, picking, ginning, etc. The cost may also be thought of as made up of the materials, or elements, necessary for production. Thus, the production of cotton requires labor, seed, fertilizer, use of machinery, use of capital, etc. Again, the cost of producing a farm product may be thought of from the standpoint of the items of direct cash outlay as compared with other cost items which are not cash. In enterprise cost-of-production studies the items of cost are usually grouped in each of the ways cited, but in the farm-business-analysis study this is impracticable because of lack of detail. However, in this study it is practicable to show the distribution of costs under six heads, viz, labor, fertilizer, use of machinery, taxes and insurance, interest on capital, and other costs, subdivided into cash and noncash items. (See Table 38.) These groupings are shown graphically in figure 8 for the farms operated by white owners and colored renters.

The item "labor" includes all of the labor on the farm whether performed by hired help, by the farmer himself, or by members of his family. The item "machinery" includes repairs, depreciation, ginning, and any other machine work hired. The item "interest on capital" represents the interest charge for the capital involved in the business. The item "other costs" includes seed bought, feed bought, horseshoeing, depreciation on mules, etc. "Cash" items include debts contracted. "Non-cash" items refer to those not paid in cash or for which no debt was contracted during the year, such as the farmer's own labor, the unpaid family labor, and the interest on the capital that is owned by the operator.

TABLE 38.—*Percentage distribution of the items of cost in producing cotton for Sumter County, Ga., 534 farms in 1913 and 550 in 1918.*

	White-owner farms.		White-tenant farms.			
			Total farm costs.		Tenant's costs.	
	1913	1918	1913	1918	1913	1918
Average total cost per acre.....	\$39.04	\$76.95	\$29.38	\$55.55	\$21.84	\$42.49
Average total cost per pound of lint.....	.122	.246	.110	.206	.103	.200
Percentage of total cost represented by:						
Labor—	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Cash.....	33.3	37.0	24.7	33.3	32.8	40.4
Noncash.....	9.8	9.2	19.0	19.3	25.3	23.4
Total.....	43.1	46.2	43.7	52.6	58.1	63.8
Fertilizer, cash.....	15.8	12.3	16.0	10.4	21.3	12.6
Machinery, cash.....	6.1	5.2	5.8	5.8	7.4	7.0
Taxes and insurance, cash.....	2.1	2.1	2.0	1.7	.5	.5
Interest on capital—						
Cash.....	2.6	1.5	.5	(¹)	.6	(¹)
Noncash.....	22.2	24.7	21.3	17.5	3.7	4.9
Total.....	24.8	26.2	21.8	17.5	4.3	4.9
Other costs—						
Cash.....	7.7	7.6	8.9	7.8	7.8	9.9
Noncash.....	.4	.4	1.8	4.2	.6	1.3
Total.....	8.1	8.0	10.7	12.0	8.4	11.2
Total costs:						
Cash.....	67.6	65.7	57.9	59.0	70.4	70.4
Noncash.....	32.4	34.3	42.1	41.0	29.6	29.6
Total.....	100.0	100.0	100.0	100.0	100.0	100.0

	Colored-owner farms.		Colored-tenant farms.			
			Total farm costs.		Tenant's costs.	
	1913	1918	1913	1918	1913	1918
Average total cost per acre.....	\$25.18	\$51.61	\$25.57	\$46.81	\$19.82	\$35.43
Average total cost per pound of lint.....	.118	.223	.105	.192	.106	.209
Percentage of total cost represented by:						
Labor—	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Cash.....	18.6	23.6	9.7	12.7	12.3	16.4
Noncash.....	22.3	23.4	34.8	36.2	44.1	46.8
Total.....	40.9	47.0	44.5	48.9	56.4	63.2
Fertilizer, cash.....	14.2	14.3	16.5	13.4	20.9	16.9
Machinery, cash.....	6.7	5.3	5.7	6.2	7.3	8.0
Taxes and insurance, cash.....	2.1	2.2	2.1	1.7	.6	.6
Interest on capital—						
Cash.....	5.0	1.6	.9	.1	1.1	.1
Noncash.....	21.3	21.8	20.4	22.7	2.9	5.1
Total.....	26.3	23.4	21.3	22.8	4.0	5.2
Other costs—						
Cash.....	7.9	6.8	8.0	6.7	8.3	5.3
Noncash.....	1.9	1.0	1.9	.3	2.5	.8
Total.....	9.8	7.8	9.9	7.0	10.8	6.1
Total costs:						
Cash.....	54.5	53.8	42.9	40.8	50.5	47.3
Noncash.....	45.5	46.2	57.1	59.2	49.5	52.7
Total.....	100.0	100.0	100.0	100.0	100.0	100.0

¹ Less than one-tenth of 1 per cent.

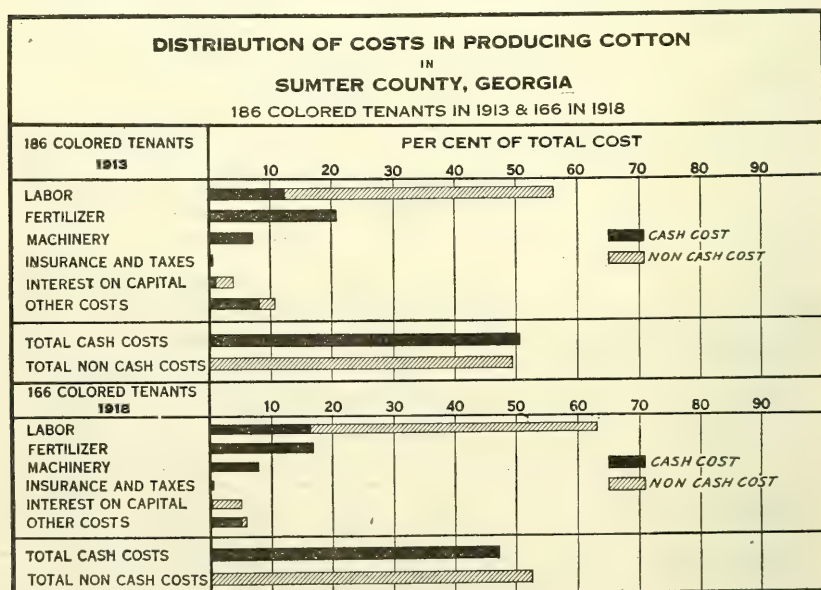
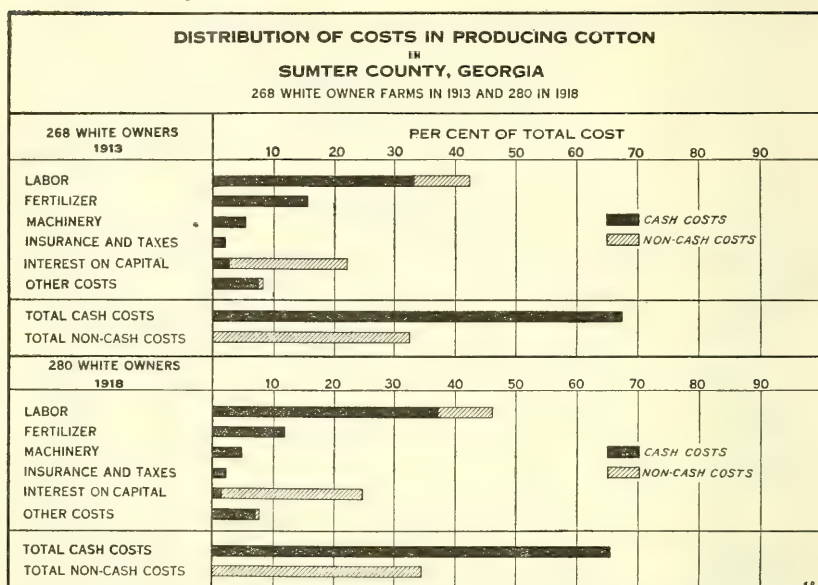


FIG. 8.—With the cost of production in 1918 almost twice that of 1913, there was very little change in the relative importance of each item of cost. Labor represented over 40 per cent of the total cost for the white owner farms each year, interest on capital almost 30 per cent, fertilizer around 15 per cent, and machinery a little over 5 per cent. The cash cost representing money paid out during the year was about two-thirds of the total, and the noncash cost, which includes the value of the farmers' labor, unpaid family labor, and interest on capital (above indebtedness), was about one-third of the total. Labor was slightly over 50 per cent of the total cost to the colored tenants and fertilizer about 20 per cent. Since most of these farms were family farms, the labor was largely noncash. About 50 per cent of the colored tenants' cost was cash and about 50 per cent noncash.

Labor represented the largest item of cost, ranging from 40.9 per cent of the total cost on colored-owner farms to 44.5 per cent of the total cost on colored-tenant farms in 1913, and from 46.2 per cent on the white-owner farms to 52.6 per cent on the white-tenant farms in 1918. The labor expense was relatively more in 1918 than in 1913. The greater part of the labor on white-owner farms was hired, while most of that on colored-tenant farms was performed by the farmers and their families.

Of the other items shown in the tables and charts, interest on capital was next in importance. This represented from 20 to 25 per cent of the total farm costs. Interest on capital was largely a noncash cost. This item of cost was of minor importance to the tenant, since his capital represented such a small proportion of the total capital involved, but to the landlord interest on capital is the largest consideration.

The expense for fertilizer was next in importance, varying from 14.2 to 16.5 per cent of the total for the farms of the several tenures in 1913, and from 10.4 to 14.3 per cent in 1918. The reduced application of fertilizer per crop acre in 1918 made this item of expense relatively less than in 1913.

Machinery represented from 5.7 to 6.7 per cent of the total costs for the farms of the several tenures in 1913 and from 5.2 to 6.2 per cent in 1918.

The cost items above mentioned represented about 90 per cent of the total costs for each class of operators each year. Taxes, insurance, and other costs represented about 10 per cent.

The cash items of cost on the white-owner farms represented 68 per cent of the total in 1913 and 66 per cent in 1918; for white tenants, 58 per cent in 1913 and 59 per cent in 1918; for colored owners, 54.5 per cent in 1913 and 54 per cent in 1918; and for colored tenants 43 per cent in 1913 and 41 per cent in 1918. Seventy per cent of the white-tenant operators' costs were cash each year, but only 50.5 per cent of the colored-tenant operators' costs in 1913, and 47.3 in 1918, were cash. Most of the labor involved in the operation of the colored-tenant farms is performed by the tenant and his family, and as labor is the largest item of expense in producing cotton, he is enabled to operate with the lowest cash costs.

The cost figure determined for each farmer concerned in this study makes full allowance for fair pay for the farmers' labor and management and a fair rate of interest upon the capital involved. Thus cotton might have been sold at a somewhat lower figure than this cost without actual loss of money, but the net return would be less than fair wages for the labor performed by the operator and his family and less than a normal interest rate upon the capital involved.

The total cost of cotton production on the farms operated by white owners in 1913 averaged 12.2 cents per pound, of which cash costs constituted 8.3 cents, the labor of the farmer and his family 1.2 cents, and interest on capital 2.7 cents. Of the total average cost of 24.6 cents per pound in 1918, the cash cost was 16.2 cents; labor, 2.3 cents; and interest, 6.1 cents.

Of the total average cost of 10.5 cents per pound for farms operated by colored tenants in 1913, the cash cost was 4.5 cents; labor, 3.8 cents; and interest on tenant's and landlord's capital, 2.2 cents. Of the total average cost of 19.2 cents per pound in 1918, the cash cost was 7.8 cents; labor, 7.0 cents; and interest on tenant's and landlord's capital, 4.4 cents.

From the standpoint of the colored tenant operator alone, out of the total cost of 10.6 cents per pound in 1913, the cash cost was 5.4 cents; labor 4.8 cents; and interest 0.4 cents. In 1918, out of the total cost of 20.9 cents per pound, the cash cost was 9.9 cents; labor, 9.8 cents; and interest, 1.2 cents.

APPENDIX.

In the following tables is presented a summary of the farm business of each of the farms covered in this study, both for the 1913 survey and for that of 1918. The farms are arranged according to the number of crop acres, farm No. 1, in each case being the farm with the smallest crop acreage in its group.

TABLE 1A.—Summary of the farm business on each of 280 white-owner farms, Sumter County, Ga., 1918.

Farm No.	Tilled acres.	Acres in cotton.	Yield of cotton per acre.	Real estate.	Other capital.	Total receipts.	Cotton receipts.	Total expenses.	Farm income.	Labor income.	Operator's labor.	Per cent return on capital.	Family labor.	Family income.	Family living from farm.	Labor income plus family living from farm.	Total months of labor.
1.....	8.00	3.00	367	\$2,150	\$281	\$701	\$395	\$246	\$455	\$285	\$175	11.5	.....	\$455	\$154	\$439	13
2.....	22.25	10.00	175	1,000	517	679	312	367	261	261	420	3.5	.....	367	475	736	12
3.....	22.75	8.00	202	2,625	601	955	560	436	519	293	75	13.8	.....	519	328	621	16
4.....	24.50	12.00	185	1,650	785	833	485	357	357	357	240	9.7	\$46	522	433	739	14
5.....	25.00	15.00	160	3,500	463	949	859	490	459	182	240	5.5	.....	459	357	539	17
6.....	25.75	10.00	168	1,700	451	683	589	396	287	136	300	6	100	387	415	551	16
7.....	27.00	8.00	125	1,720	675	417	378	357	60	108	240	7.5	.....	357	484	376	15
8.....	27.25	9.00	222	2,600	1,002	899	668	584	315	63	300	7.9	240	555	427	490	24
9.....	28.00	4.00	125	1,500	400	499	199	278	221	88	200	1.1	.....	221	452	540	16
10.....	29.00	6.00	183	1,725	696	731	375	340	391	222	250	5.8	140	531	588	810	19
11.....	29.00	6.00	232	1,100	504	773	415	357	416	304	250	10.4	50	466	538	842	14
12.....	29.50	14.00	161	2,831	293	890	744	326	564	345	220	11.0	75	639	371	716	15
13.....	30.50	12.00	255	1,800	727	1,392	1,022	1,205	187	10	100	3.4	.....	187	458	468	24
14.....	31.25	12.00	154	698	302	1,608	546	933	179	109	360	18.1	120	299	326	435	18
15.....	33.00	18.00	214	2,000	1,360	1,631	1,489	983	698	463	480	6.5	480	1,178	774	1,237	24
16.....	34.00	3.00	333	3,750	761	753	378	612	141	175	300	3.5	280	421	553	378	26
17.....	34.00	9.00	167	1,720	566	661	504	215	446	215	300	6.4	.....	446	426	712	14
18.....	34.50	10.00	150	1,825	858	769	473	405	364	176	360	2	100	464	440	616	17
19.....	36.00	7.00	179	1,080	772	502	396	529	27	157	420	24.1	160	133	566	409	22
20.....	36.00	7.00	214	3,750	1,093	889	523	320	569	230	600	6	50	619	498	728	15
21.....	36.00	4.00	525	3,000	1,023	1,229	732	312	917	635	600	7.9	.....	917	431	1,066	13
22.....	36.25	20.00	225	3,750	1,315	2,494	1,701	608	1,514	1,159	360	22.8	.....	1,514	372	1,275	22
23.....	37.25	6.00	125	1,500	48	1,22	494	608	94	14	360	17.2	30	124	289	1,275	13
24.....	37.25	4.00	338	1,600	549	947	484	307	640	490	360	13.0	.....	640	275	765	13
25.....	37.50	15.00	133	2,450	808	1,169	709	715	454	226	400	1.7	165	619	676	902	23
26.....	39.25	12.00	167	1,500	1,219	930	707	432	498	308	240	9.5	120	618	606	914	20
27.....	39.50	15.00	272	4,000	1,639	1,639	1,290	846	793	471	300	15.1	.....	793	431	902	27
28.....	42.75	24.00	211	2,266	1,001	2,170	1,814	1,041	1,129	761	100	15.8	.....	1,129	218	979	31
29.....	43.00	13.00	231	2,280	1,223	1,619	1,036	570	1,049	804	360	19.7	.....	1,049	644	1,448	22
30.....	46.00	16.00	203	3,000	1,566	1,191	1,084	914	277	38	360	1.8	.....	277	609	571	22

^a Includes crop land rented out.

TABLE 1A.—Summary of the farm business on each of 280 white-owner farms, Sumter County, Ga., 1918—Continued.

Farm No.	Tilled acres.	Acres in cotton.	Yield of cotton per acre.	Real estate.	Other capital.	Total receipts.	Cotton receipts.	Total expenses.	Farm income.	Labor income.	Operator's labor.	Percent return on capital.	Family labor.	Family income.	Family living from farm.	Labor income plus family living from farm.	Total months of labor.
31.	46.00	20.00	150	\$3,000	\$952	\$1,133	\$979	\$443	\$690	\$413	\$600	2.3		\$600	\$576	\$989	10
32.	46.25	10.00	125	3,180	762	1,222	385	742	480	204	240	6.1		480	309	513	21
33.	46.50	6.00	107	5,955	562	1,433	213	263	809	—	180	2	\$20	210	367	521	23
34.	46.50	21.00	187	4,000	1,030	1,859	1,631	970	1,069	515	200	13.2		859	363	878	23
35.	47.75	7.00	157	2,945	957	1,522	453	691	831	538	365	11.9		831	478	1,036	25
36.	48.00	9.00	160	5,000	675	592	322	453	49	348	240	—	3.4	100	1,251	886	15
37.	49.50	8.00	250	5,038	798	1,054	612	870	184	85	120	1.7	25	209	373	288	26
38.	51.75	30.00	167	1,960	705	1,809	1,740	755	1,051	807	195	32.2	390	1,444	299	1,666	29
39.	52.25	25.00	280	8,750	1,125	2,280	2,168	1,221	1,059	368	360	7.1	150	1,209	480	1,115	40
40.	52.25	12.00	208	2,500	1,521	1,688	900	769	919	638	350	14.2	200	1,119	477	1,115	24
41.	55.00	15.00	183	4,900	1,553	1,676	929	874	802	350	240	8.7	300	1,102	763	1,113	28
42.	55.50	28.00	232	8,700	943	2,304	2,143	1,434	870	195	480	4.0		870	650	845	36
43.	55.75	15.00	167	2,312	911	1,338	849	1,037	301	75	300		25	326	448	523	24
44.	55.75	15.00	333	6,360	1,914	2,248	1,744	845	1,433	851	600	10.1	100	1,533	807	1,661	28
45.	56.00	20.00	275	7,500	2,281	2,601	1,982	1,240	1,361	676	250	11.4		1,361	613	1,289	40
46.	56.25	30.00	283	8,000	1,697	4,026	2,924	2,478	1,548	869	360	12.2		1,548	240	1,109	36
47.	56.50	12.00	188	5,325	1,352	1,382	640	574	808	376	240	9.2	210	1,018	490	1,806	22
48.	56.50	8.00	156	4,000	219	1,133	460	440	633	398	640	2.2	100	733	537	935	18
49.	56.50	20.00	350	6,250	1,370	3,052	2,703	961	2,091	1,558	729	18.0		2,091	234	1,792	32
50.	57.00	25.00	240	4,000	1,560	2,595	2,021	1,411	1,184	795	360	13.8		1,184	648	1,443	34
51.	57.50	13.00	192	4,330	1,673	1,028	686	1,204	776	540	300	9.2	180	4	776	236	34
52.	57.75	5.00	200	7,500	1,673	1,414	368	705	—	67	400	3.4	240	949	940	1,007	24
53.	60.00	6.00	250	6,080	519	821	506	447	374	88	300	1.1	65	439	342	254	15
54.	60.00	8.00	125	2,520	1,357	918	290	355	563	292	420	3.7		563	523	815	14
55.	60.00	16.00	219	3,250	2,146	1,610	1,230	643	907	589	300	12.4		967	467	1,056	23
56.	60.75	20.00	350	10,300	2,059	3,436	2,510	1,218	2,218	1,353	600	13.1	150	2,368	712	2,065	31
57.	61.50	20.00	325	6,500	1,577	2,986	2,288	1,660	1,326	761	360	12.0		1,326	572	1,333	30
58.	61.50	18.00	222	5,000	2,796	1,332	1,332	1,207	1,589	1,114	300	19.0		1,589	421	1,635	30
59.	62.50	19.00	211	3,840	2,271	2,180	1,442	1,338	842	1,114	400	7.2	62	904	409	1,513	29
60.	63.25	26.00	231	8,100	1,645	2,622	2,097	1,432	1,130	508	600	6.0	220	1,410	1,582	1,090	41
61.	63.50	42.00	179	4,800	706	2,690	2,556	1,802	888	503	600	5.2		888	347	850	54
62.	63.50	24.00	208	4,960	1,632	2,248	1,707	998	1,252	791	360	13.5	300	1,277	420	1,211	32
63.	63.75	25.00	280	6,000	2,693	2,693	2,508	1,695	1,695	1,167	480	16.1		1,995	908	2,075	28

64.	64.25	20.00	225	7,700	1,728	2,601	1,601	1,095	1,506	846	600	9.6	1,506	927	1,773	27
65.	64.50	28.00	156	6,000	1,630	2,003	1,519	1,369	1,634	170	360	4.1	634	347	517	27
66.	65.00	27.00	167	3,600	1,383	2,055	1,574	1,844	211	138	120	1.8	211	409	271	42
67.	66.25	18.00	222	15,600	2,297	1,693	1,412	1,050	643	610	480	.9	673	963	353	24
68.	66.75	4.00	188	3,200	2,006	1,906	2,262	1,778	128	236	240	2.2	148	646	410	22
69.	68.50	35.00	186	6,500	1,062	2,242	1,996	1,630	612	83	200	5.4	612	647	730	44
70.	68.50	30.00	133	2,500	1,508	1,886	1,384	1,234	652	371	80	14.3	652	333	704	48
71.	68.50	27.00	185	4,000	1,731	2,272	1,708	1,217	1,055	654	600	7.9	1,055	447	1,026	33
72.	68.75	35.00	314	7,500	1,957	4,348	4,022	2,287	1,961	1,369	600	16.1	1,961	657	2,101	30
73.	69.75	35.00	236	2,250	1,979	3,193	2,948	1,592	1,601	1,305	360	29.3	1,601	418	1,723	35
74.	70.25	30.00	125	4,400	1,397	1,478	1,252	823	655	249	360	5.1	967	377	1,736	26
75.	71.50	10.00	72	3,500	1,764	1,701	258	627	1,074	706	360	13.6	1,434	539	1,245	30
76.	a 72.00	27.00	311	4,375	1,861	2,930	2,488	1,346	1,584	1,147	400	19.0	1,619	914	2,061	36
77.	72.00	14.00	286	10,125	2,545	2,545	1,359	1,414	1,131	1,279	300	6.8	1,131	477	756	29
78.	74.00	20.00	300	12,000	2,836	4,452	2,294	2,287	2,165	1,125	900	8.5	2,165	944	2,069	30
79.	74.25	20.00	325	5,000	2,336	2,924	2,151	1,780	1,144	70	420	4.2	1,144	628	558	48
80.	75.00	35.00	262	4,000	2,422	3,611	3,096	1,027	2,584	2,134	600	30.9	2,674	512	2,646	29
81.	75.75	23.00	152	3,000	1,612	1,756	1,125	1,292	464	141	200	5.7	464	333	474	34
82.	75.75	16.00	125	9,500	1,926	2,270	1,680	1,299	971	171	300	5.9	1,071	538	729	42
83.	a 75.75	15.00	267	9,300	1,208	1,780	1,358	562	1,218	483	300	8.7	1,326	684	1,167	41
84.	75.75	30.00	233	5,000	2,402	2,579	2,302	1,254	1,325	807	360	13.0	1,865	724	1,531	20
85.	76.25	18.00	250	2,300	1,296	2,755	1,515	1,470	1,285	1,033	480	22.4	1,285	460	1,493	39
86.	a 76.75	14.00	214	7,000	1,529	1,634	1,032	1,100	534	63	300	2.7	534	352	289	36
87.	77.25	16.00	469	10,000	2,503	4,669	2,648	2,648	2,021	1,146	480	12.3	2,021	736	1,882	41
88.	77.50	34.00	170	7,000	1,832	2,764	1,814	950	950	330	700	2.8	950	494	824	44
89.	78.25	25.00	320	10,000	2,088	3,695	2,838	2,351	1,344	498	300	8.6	1,344	555	1,053	28
90.	78.25	22.00	250	15,000	3,173	3,613	1,918	1,808	1,805	533	1,200	3.3	1,805	880	1,413	56
91.	78.50	24.00	229	5,000	1,289	2,491	1,954	1,495	906	556	420	9.2	1,021	558	1,114	30
92.	78.50	24.00	229	9,500	2,174	4,772	1,927	1,883	2,586	1,769	250	20.0	2,586	641	2,410	38
93.	80.75	40.00	184	4,000	2,149	2,792	2,556	1,829	966	536	500	7.6	1,326	943	1,079	42
94.	81.75	32.00	219	4,905	1,641	2,829	2,500	1,575	1,254	706	480	11.8	1,254	481	1,277	35
95.	82.50	24.00	504	10,250	4,430	7,004	4,425	3,870	3,128	2,100	600	17.2	3,128	1,357	3,437	72
96.	83.00	30.00	217	7,500	1,909	3,812	2,482	1,282	2,530	1,871	500	21.6	2,530	402	2,273	41
97.	83.75	50.00	180	10,000	2,973	3,315	2,701	2,669	1,246	478	300	8.6	1,246	38	516	57
98.	a 84.25	12.00	421	18,400	2,006	2,857	1,735	1,827	1,530	398	600	2.1	1,030	566	108	40
99.	85.00	40.00	123	4,680	1,084	1,976	1,735	1,330	1,337	357	360	6.6	900	456	793	34
100.	86.50	30.00	192	4,510	1,918	3,063	2,174	1,267	1,775	1,328	360	22.1	1,775	522	1,890	34
101.	88.25	20.00	300	6,000	1,608	3,107	2,002	762	2,345	1,812	480	24.5	2,345	559	2,351	22
102.	88.25	42.00	333	8,025	1,765	6,094	4,814	2,786	3,248	2,563	350	29.6	3,248	571	3,134	50
103.	a 88.25	27.00	102	6,730	1,700	1,813	990	1,298	515	81	100	4.9	515	502	421	35
104.	88.75	24.00	241	12,600	4,419	3,180	2,415	1,907	1,573	352	300	6.3	1,573	443	825	28
105.	88.75	24.00	333	20,000	2,451	3,648	2,839	2,794	1,894	718	300	2.5	1,894	506	212	59

a Includes crop and rented out.

TABLE 1A.—Summary of the farm business on each of 280 white-owner farms, Sumter County, Ga., 1918—Continued.

Farm No.	Tilled acres.	Acres in cotton.	Yield of cotton per acre.	Real estate.	Other capital.	Total receipts.	Cotton receipts.	Total expenses.	Farm income.	Labor income.	Operator's labor.	Percent return on capital.	Family labor.	Family income.	Family living from farm.	Labor income plus family living from farm.	Total months of labor.
106.	91.50	20.00	175	\$15,540	\$1,220	\$2,208	\$1,203	\$984	\$1,224	\$51	\$600	3.7	.....	\$1,224	\$558	\$609	16
107.	92.00	30.00	342	5,385	3,385	4,946	3,376	1,363	2,260	1,309	600	12.2	.....	2,260	841	2,150	54
108.	92.25	35.00	321	5,800	1,632	2,588	1,909	1,363	1,225	705	600	8.4	.....	1,225	514	1,219	38
109.	92.00	28.00	314	11,800	1,599	4,204	3,293	2,998	3,206	2,268	900	17.2	83	3,256	1,005	3,273	29
110.	94.75	40.00	238	7,500	1,374	3,653	3,024	2,550	1,093	472	50	11.8	.....	1,093	615	1,087	55
111.	95.50	45.00	156	12,000	2,728	3,177	2,460	1,458	1,719	688	360	7.5	440	2,159	730	1,418	45
112.	96.00	40.00	262	6,800	4,212	4,212	3,166	3,166	774	—	500	2.3	65	2,339	1,027	1,977	80
113.	96.00	30.00	267	7,500	2,149	4,175	2,888	3,210	965	290	600	3.8	.....	965	1,046	1,036	49
114.	96.00	30.00	333	7,500	2,033	5,711	3,520	2,274	3,437	2,770	600	29.8	.....	3,437	406	3,176	52
115.	97.00	34.00	221	9,000	1,355	3,409	2,635	1,764	1,645	920	480	11.2	.....	1,645	684	1,604	40
116.	97.75	25.00	140	2,700	1,410	1,610	1,216	1,203	407	119	360	1.1	.....	407	330	449	31
117.	98.25	35.00	271	14,000	2,117	4,813	3,403	2,345	2,468	1,340	750	10.7	240	2,708	877	2,217	53
118.	98.50	28.00	500	14,000	4,113	6,649	4,792	2,006	4,643	3,375	600	22.3	.....	4,643	769	4,144	32
119.	99.50	38.00	92	2,851	1,612	1,465	1,219	2,019	4,786	474	300	10.9	240	1,026	662	1,136	25
120.	99.75	22.00	205	15,000	2,468	2,533	1,395	2,016	517	706	450	.4	200	717	860	154	37
121.	100.75	40.00	294	3,300	1,683	4,350	3,567	2,602	1,748	1,399	300	29.1	85	1,833	523	1,922	64
122.	101.50	48.00	312	11,200	6,385	5,330	5,330	3,181	3,204	2,204	1,000	15.4	110	3,314	942	3,146	68
123.	102.00	80.00	231	8,760	1,621	5,985	5,797	4,672	1,313	586	250	10.2	.....	1,313	.....	586	65
124.	105.25	27.00	162	3,750	1,558	2,747	2,641	2,336	1,411	39	480	1.3	40	3,553	837	876	48
125.	105.25	27.00	348	8,400	4,609	6,491	3,275	2,838	3,553	2,642	360	24.5	.....	3,553	706	3,348	51
126.	107.00	37.00	297	7,050	4,586	4,586	3,883	3,090	1,495	853	900	6.5	.....	1,495	803	1,656	66
127.	107.00	33.00	220	15,300	2,075	3,239	2,589	1,903	1,336	120	480	4.9	.....	1,336	471	591	44
128.	108.25	40.00	375	17,500	2,134	6,523	5,268	4,283	2,240	866	400	9.4	.....	2,240	1,191	2,057	80
129.	110.00	32.00	312	20,000	3,420	3,420	3,460	3,123	2,297	673	900	15.2	.....	2,297	710	1,383	72
130.	110.25	55.00	209	8,000	2,287	4,535	4,266	2,606	1,929	1,209	360	15.2	672	2,601	1,600	1,815	53
131.	111.50	32.00	359	15,000	3,912	6,098	4,049	4,087	2,011	687	700	6.9	.....	2,011	856	1,543	63
132.	112.50	55.00	345	15,600	2,666	6,444	5,829	4,984	1,800	1,730	480	5.4	150	1,630	612	1,791	57
133.	113.75	40.00	125	8,500	1,711	2,406	1,767	1,406	1,000	285	300	7.4	.....	1,000	423	708	35
134.	115.25	9.00	158	8,100	1,983	2,014	1,429	1,108	846	189	200	5.2	50	896	569	738	29
135.	117.00	13.00	133	5,000	3,270	1,558	687	1,100	698	119	200	6.0	.....	698	687	806	19
136.	117.00	34.00	140	4,500	1,234	2,536	1,609	1,813	723	322	300	7.4	.....	723	390	712	55
137.	122.00	51.00	209	16,000	2,843	4,675	3,829	3,184	1,491	1,772	480	5.4	600	2,091	993	1,165	77
138.	123.25	55.00	177	6,975	1,370	3,544	2,933	2,617	1,927	343	600	3.9	.....	1,927	1,040	1,353	71

139	123.25	42.00	262	23,000	3,568	5,865	3,921	3,409	2,456	596	600	7.0	60	2,516	934	1,530	77
140	124.00	50.00	150	8,000	2,096	3,264	2,986	2,497	2,767	60	200	5.6	.....	767	879	939	39
141	124.75	53.00	307	10,125	3,279	8,118	5,944	4,813	3,305	2,367	600	20.2	.....	3,305	1,042	3,409	89
142	126.50	26.00	220	17,500	2,164	3,305	1,753	1,548	1,757	3,381	500	6.4	.....	1,757	945	3,409	37
143	126.50	43.00	326	15,300	6,121	6,969	5,205	4,187	2,782	1,853	600	10.7	.....	2,782	628	1,981	58
144	131.00	55.00	236	11,825	3,037	7,535	4,733	3,230	4,305	1,265	600	24.9	40	4,345	972	4,237	73
145	131.00	12.00	333	7,500	803	2,948	1,378	1,000	1,948	1,366	1,100	10.2	400	2,348	.....	1,366	28
146	133.00	42.00	305	15,480	2,522	6,438	4,310	4,679	1,759	499	450	7.3	.....	1,759	714	1,213	65
147	133.75	15.00	283	10,000	787	2,384	1,517	954	1,430	675	300	10.4	.....	1,430	571	1,246	22
148	135.50	40.00	338	14,250	2,794	5,641	4,499	3,237	2,404	1,211	1,200	7.1	.....	2,404	1,091	2,302	52
149	136.75	53.00	325	12,500	3,775	4,856	2,290	2,279	2,577	1,438	900	12.2	200	2,777	1,267	2,705	76
150	137.00	33.00	377	7,850	3,734	9,060	6,882	4,104	4,956	4,145	360	38.7	120	3,076	582	4,727	82
151	138.75	43.00	203	14,320	2,721	4,022	3,079	2,240	1,782	589	400	8.1	.....	1,782	661	1,250	54
152	139.50	45.00	71	12,000	2,504	1,792	1,121	1,358	434	581	480	7.5	175	1,430	580	1	44
153	140.00	50.00	180	9,750	1,426	3,601	2,430	2,615	986	204	150	7.3	360	1,346	841	1,045	55
154	140.25	65.00	203	10,000	4,357	6,113	4,888	3,495	2,618	1,613	500	14.8	50	2,608	999	2,312	68
155	142.00	45.00	167	22,500	2,777	3,863	2,612	2,889	2,974	795	480	2.0	420	1,394	961	166	86
156	143.00	63.00	246	12,375	3,889	7,057	5,341	4,389	2,668	1,530	420	13.8	.....	2,668	755	2,285	100
157	143.25	46.00	129	9,125	6,449	3,387	1,407	2,760	3,627	463	250	2.4	.....	3,627	391	72	68
158	144.00	46.00	238	6,800	1,511	7,498	3,934	3,926	3,572	2,990	480	37.2	200	3,772	759	3,749	63
159	145.50	45.00	267	20,200	3,773	5,837	4,104	3,353	2,484	806	600	7.9	20	2,504	1,175	3,981	62
160	147.00	45.00	311	14,175	4,529	6,846	4,948	3,802	3,044	1,735	1,200	9.9	.....	3,044	573	2,308	82
161	148.50	36.00	250	16,850	2,897	4,347	3,390	2,976	1,371	11	600	3.9	.....	1,371	738	727	39
162	149.00	18.00	104	15,000	927	3,002	1,182	1,554	1,448	333	200	7.8	.....	1,448	492	825	24
163	149.00	85.00	294	9,400	3,359	9,362	8,696	4,872	4,490	3,597	1,000	27.4	.....	4,490	315	3,912	114
164	150.25	51.00	216	9,750	3,615	4,400	3,338	2,982	1,418	482	400	7.6	.....	1,418	313	795	56
165	153.25	65.00	385	14,625	4,517	10,644	8,420	6,338	4,306	2,966	600	19.4	.....	4,306	602	3,568	87
166	154.75	31.00	155	12,000	3,598	3,863	1,602	2,268	1,595	503	600	6.4	.....	1,595	792	1,295	39
167	155.50	75.00	247	15,000	1,622	7,749	6,437	5,137	2,612	1,448	1,200	8.5	.....	2,612	103	1,551	67
168	155.50	55.00	273	25,000	3,215	6,615	5,334	4,594	2,021	46	1,500	1.8	.....	2,021	1,446	1,492	96
169	161.00	36.00	286	25,000	1,970	4,782	3,435	3,173	1,609	279	1,000	2.3	.....	1,609	1,406	1,127	54
170	165.75	45.00	233	10,000	3,203	4,704	3,599	4,414	2,690	634	1,200	6.9	480	1,779	900	266	60
171	166.00	59.00	205	20,200	4,043	5,748	4,475	3,649	2,099	402	1,000	4.5	.....	2,099	885	1,287	98
172	167.75	67.00	144	16,720	2,921	4,860	3,383	2,381	1,006	400	400	10.1	100	2,481	615	1,621	53
173	168.00	50.00	300	15,750	3,602	8,247	5,212	4,506	3,741	2,386	500	16.8	.....	3,741	625	3,011	104
174	174.75	40.00	350	32,250	7,539	11,865	4,393	4,588	7,277	4,492	1,000	15.3	50	1,221	5,713	7,327	89
175	175.25	85.00	229	15,300	3,948	6,718	6,652	3,333	3,385	2,038	1,200	12.4	200	3,585	1,220	3,258	72
176	176.00	86.00	298	32,000	5,825	10,863	9,219	4,774	6,089	3,441	600	14.5	.....	6,089	671	4,112	88
177	176.50	75.00	313	12,150	4,784	9,970	7,930	6,728	3,242	2,057	300	17.4	.....	3,242	665	2,722	114
178	181.00	45.00	311	27,500	5,290	7,897	4,881	5,730	2,167	1,266	1,000	3.6	.....	2,167	729	603	87
179	181.50	75.00	200	21,000	4,453	7,779	5,236	2,474	2,474	692	500	7.8	80	2,554	1,916	1,916	120
180	182.25	68.00	257	26,100	5,237	7,975	6,102	5,129	2,846	652	1,500	4.3	.....	2,846	939	1,591	122

a Includes crop land rented out.

TABLE 1A.—Summary of the farm business on each of 280 white-owner farms, Sumter County, Ga., 1918—Continued.

Farm No.	Tilled acres.	Acres in cotton.	Yield of cotton per acre.	Real estate.	Other capital.	Total receipts.	Cotton receipts.	Total ex-penses.	Farm income.	Labor income.	Operator's labor.	Percent return on capital.	Family labor.	Family income.	Family living from farm.	Labor income plus family living from farm.	Total months of labor.
181.....	184.00	90.00	250	\$18,000	\$3,917	\$10,952	\$7,680	\$6,390	\$4,562	\$3,028	\$1,200	15.3	.....	\$4,562	\$719	\$3,747	88
182.....	a 184.50	20.00	368	16,560	2,630	5,202	3,192	1,096	4,106	2,703	600	18.3	.....	4,106	571	3,334	37
183.....	186.25	120.00	333	20,000	8,897	15,442	14,144	7,096	8,360	6,337	600	26.8	.....	8,360	559	6,896	115
184.....	186.75	80.00	250	12,900	3,581	9,316	5,700	5,571	3,745	2,591	600	19.1	\$300	4,045	774	3,365	74
185.....	a 187.25	33.00	167	30,000	1,311	3,531	1,879	2,102	1,429	—	100	4.2	.....	1,429	363	—	59
186.....	190.25	115.00	426	30,000	5,439	19,371	17,068	9,443	9,928	7,447	1,800	22.9	.....	9,928	1,133	8,580	170
187.....	195.50	100.00	350	26,500	4,428	14,521	12,120	8,179	6,342	4,177	1,200	18.9	.....	6,342	1,320	5,497	124
188.....	198.50	46.00	234	24,000	4,467	5,264	3,645	4,418	846	-1,147	1,200	—	400	1,246	1,440	293	92
189.....	a 198.50	55.00	291	17,500	4,243	8,780	5,741	4,810	3,970	2,448	600	14.6	.....	3,970	792	3,240	79
190.....	200.75	40.00	186	29,100	4,834	6,492	2,587	3,944	2,548	1,173	600	5.7	230	2,778	831	1,004	88
191.....	202.25	48.00	333	14,400	7,706	8,959	5,667	4,596	4,363	2,816	900	15.7	.....	4,363	820	3,636	68
192.....	a 202.50	60.00	267	18,750	4,511	8,977	5,878	4,839	4,138	2,510	500	15.6	.....	4,138	984	3,494	71
193.....	204.00	76.00	223	16,800	2,754	8,132	5,830	4,756	3,378	2,037	480	14.8	40	3,416	1,181	3,188	104
194.....	204.50	80.00	324	28,800	6,183	11,495	8,740	6,895	4,600	2,151	1,200	9.7	.....	4,600	1,873	4,024	116
195.....	a 204.75	45.00	189	9,450	1,571	4,076	2,850	4,182	—	597	240	—	.....	106	840	243	62
196.....	a 206.00	40.00	250	19,250	2,369	4,749	3,410	3,555	1,194	—	450	3.4	.....	1,194	629	310	80
197.....	a 207.50	40.00	162	4,750	1,582	4,141	2,256	1,598	2,543	2,100	500	32.3	100	2,643	693	2,793	44
198.....	a 208.50	57.00	333	18,680	2,616	7,267	6,460	4,055	3,212	1,721	50	14.8	.....	3,212	683	2,404	92
199.....	220.50	90.00	250	26,172	3,456	10,308	6,556	6,780	2,528	1,384	800	8.9	.....	2,528	1,039	2,423	96
200.....	222.50	74.00	223	32,475	3,580	8,370	5,842	3,172	5,198	2,674	1,200	11.1	260	5,458	1,769	3,443	76
201.....	a 222.75	35.00	214	31,200	3,000	4,925	2,876	2,470	2,435	61	900	4.6	.....	2,435	100	161	51
202.....	225.00	60.00	508	20,000	3,828	13,126	9,098	8,471	4,658	2,850	600	15.7	.....	4,658	692	3,542	108
203.....	a 231.00	100.00	425	47,250	11,914	20,267	15,120	7,107	13,160	9,066	1,800	19.4	.....	13,160	1,268	10,334	135
204.....	232.25	60.00	292	24,375	5,922	8,313	5,770	5,851	2,462	341	1,200	4.2	.....	2,462	506	847	58
205.....	a 232.25	40.00	212	11,325	5,991	6,793	2,929	5,113	1,680	468	500	8.0	.....	1,680	417	885	110
206.....	232.50	81.00	173	12,200	4,466	5,704	4,802	4,669	1,035	—	500	3.2	.....	1,035	719	587	99
207.....	a 232.50	35.00	371	20,000	2,749	6,667	4,332	2,397	2,290	698	75	9.7	.....	2,290	975	1,673	57
208.....	a 233.00	50.00	385	42,500	4,846	8,338	3,381	5,032	1,506	-1,908	800	1.8	.....	1,506	1,359	—	70
209.....	246.75	75.00	187	18,000	5,603	7,228	4,068	4,685	2,583	877	700	7.8	60	2,593	1,016	1,893	77
210.....	247.00	150.00	300	40,000	6,188	17,017	16,743	8,205	6,223	5,579	600	17.8	.....	6,223	546	6,125	154
211.....	248.50	75.00	267	28,875	7,104	12,560	6,544	6,337	6,223	3,704	1,000	14.5	.....	6,223	862	4,566	117
212.....	a 249.00	75.00	188	15,750	2,151	5,651	4,062	3,351	1,670	417	1,000	8.8	.....	1,670	544	1,491	108
213.....	a 249.50	95.00	211	30,000	4,713	7,694	6,774	5,058	2,636	206	600	5.9	.....	2,636	1,280	1,486	83

214	252.00	181.00	206	16,000	4,557	14,403	13,357	7,341	7,082	5,623	600	31.4	500	7,562	910	5,533	123
215	259.00	40.00	300	29,910	5,445	7,678	6,774	5,192	2,486	11	800	4.8		2,486	809	884	84
216	260.25	64.00	298	51,000	6,979	8,606	6,744	7,991	615	-3,444	420	3		615	1,150	-2,294	98
217	264.75	40.00	162	14,000	6,433	5,581	2,267	4,193	1,368	62	480	4.4		1,368	731	669	94
218	270.75	40.00	296	26,000	4,126	7,302	3,897	3,276	4,026	1,917	600	11.4		4,026	712	2,629	45
219	271.00	75.00	200	19,000	3,778	7,490	5,418	5,790	1,700	36	770	3.8	770	2,470	845	881	126
220	275.75	125.00	136	34,000	3,252	6,516	5,582	3,776	2,740	832	350	8.8		2,740	426	1,258	64
221	276.75	105.00	105	22,500	3,630	5,371	3,547	5,155	216	-1,613	600	-		216	891	-	139
222	279.00	61.00	322	27,400	4,358	9,230	7,147	7,501	1,729	404	900	2.6	330	2,059	948	454	94
223	280.50	140.00	64	13,500	2,901	4,220	3,069	4,057	1,653	-991		1.0		1,653	943	-	93
224	283.00	74.00	179	34,200	5,830	7,823	3,474	4,941	2,882	80	900	5.0		2,882	903	983	93
225	287.00	90.00	128	18,300	3,716	7,353	3,942	3,207	4,156	2,615	600	16.2		4,156	344	2,959	106
226	298.00	95.00	280	35,040	3,755	10,469	9,483	9,491	978	-1,738	800	5		978	907	-	138
227	317.00	43.00	223	23,950	7,169	12,425	6,520	4,835	7,590	5,412	900	21.5		7,590	908	6,318	84
228	318.50	118.00	276	50,000	10,925	13,655	10,940	8,600	5,055	790	700	7.2		5,055	1,444	2,234	138
229	332.25	100.00	180	20,000	5,903	6,496	6,069	4,522	1,974	161	1,200	3.0		1,974	786	947	79
230	342.00	125.00	250	23,800	4,396	16,352	11,902	8,442	7,920	5,946	1,200	23.8		7,920	816	6,762	90
231	343.00	60.00	375	56,250	4,771	10,389	7,589	5,859	4,530	239	360	6.8		4,530	450	709	90
232	343.25	125.00	560	30,000	18,653	31,686	23,734	15,532	16,154	12,748	3,169	26.7		16,154	1,252	14,000	257
233	347.25	84.00	214	34,400	6,114	9,158	6,353	4,821	4,337	1,501	1,200	7.7	100	4,437	874	2,375	98
234	357.50	21.00	238	16,000	1,453	3,927	1,745	1,436	2,491	1,269	480	11.5	80	2,571	903	2,172	39
235	357.75	54.00	222	54,300	3,697	7,648	4,153	3,886	3,762	-298	1,000	4.8		3,762	1,063	7,765	110
236	358.50	30.00	167	30,000	2,432	4,386	1,781	1,890	2,496	226	500	6.2	45	2,541	587	813	31
237	361.50	180.00	231	27,400	7,133	15,477	13,256	11,329	4,148	1,731	1,000	9.1		4,148	1,077	2,808	158
238	365.50	205.00	217	30,000	6,284	17,741	15,421	11,201	6,510	4,000	600	16.4		6,510	802	3,802	197
239	368.75	190.00	376	50,000	14,419	34,172	25,186	11,705	22,467	17,958	1,200	33.9		22,467	1,003	18,961	250
240	378.25	100.00	340	37,500	2,312	15,858	12,298	7,951	7,907	3,720	1,500	10.7		7,907	1,102	4,822	152
241	388.00	200.00	288	53,800	7,928	21,529	20,331	13,366	8,163	3,842	500	12.4		8,163	748	4,590	177
242	395.00	140.00	307	51,250	9,285	18,617	15,105	9,940	8,077	4,720	1,500	12.7	90	8,767	1,304	6,024	189
243	403.75	150.00	350	60,750	10,768	28,325	18,731	18,613	9,912	4,906	900	12.6	10	9,922	725	3,631	285
244	432.00	140.00	357	47,500	11,318	21,214	17,634	13,485	7,729	3,629	1,200	13.7		7,729	1,231	4,860	217
245	443.75	150.00	290	45,000	10,377	20,957	16,160	9,826	11,161	8,650	1,000	23.3		11,161	857	9,507	208
246	450.50	191.00	173	28,000	8,946	15,348	11,673	9,622	5,726	3,140	1,500	11.4	300	6,026	657	3,797	195
247	459.75	130.00	229	45,900	9,474	18,626	15,026	11,333	7,293	3,417	1,000	11.4		7,293	650	4,007	189
248	462.90	160.00	250	38,000	6,175	14,068	11,073	9,885	4,173	1,291	1,500	6.5		4,173	605	1,956	148
249	467.75	104.00	230	42,000	4,208	12,541	7,523	6,527	6,014	3,451	1,500	13.7	300	6,314	1,035	4,486	132
250	495.00	172.50	290	43,750	9,591	20,053	17,526	9,619	10,434	6,700	1,200	17.3		10,434	1,353	7,053	192
251	531.00	220.00	258	88,500	12,603	31,917	21,193	19,686	12,261	5,184	1,200	10.9	440	12,701	1,266	6,450	339
252	531.00	230.00	252	59,500	9,985	20,118	21,231	14,435	14,335	9,571	450	20.1		14,435	373	9,944	196
253	536.00	43.00	174	65,000	24,664	15,552	2,623	8,699	6,853	5,577	1,000	6.5		6,853	632	1,209	211
254	543.50	120.00	183	10,609	10,609	14,468	7,424	10,654	4,322	885	1,800	3.4	4,414	4,414	1,044	1,596	145
255	554.75	72.00	250	95,400	3,044	10,668	6,353	6,342	4,424	-2,569	1,200	3.2		4,424	1,573	-1,996	145

² Includes crop land rented out.

TABLE 1A.—Summary of the farm business on each of 280 white-owner farms, Sumter County, Ga., 1918—Continued.

Farm No.	Tilled acres.	Acres in cotton.	Yield of cotton per acre.	Real estate.	Other capital.	Total receipts.	Cotton receipts.	Total expenses.	Farm income.	Labor income.	Operator's labor.	Percent return on capital.	Family labor.	Family income.	Family living from farm.	Labor income plus family living from farm.	Total months of labor.
256.....	a 559.50	140.00	254	\$38,000	\$3,103	\$15,486	\$12,281	\$7,081	\$8,405	\$5,528	\$500	19.2	.....	\$8,405	\$551	\$6,079	148
257.....	a 564.75	90.00	383	45,000	3,366	17,554	12,215	7,628	9,906	6,520	600	19.2	.....	9,906	741	7,261	100
258.....	a 596.75	148.00	243	56,000	6,908	16,757	12,549	9,904	6,853	4,409	1,000	16.8	.....	6,853	1,152	5,561	136
259.....	a 601.50	75.00	400	28,250	8,269	25,698	11,464	9,593	16,105	11,589	1,000	23.4	.....	16,105	1,308	12,897	144
260.....	a 616.75	236.00	178	82,500	12,075	20,992	14,766	13,531	5,441	-1,179	1,200	4.5	.....	5,441	1,040	—	239
261.....	a 625.00	246.00	285	50,000	14,943	32,370	25,496	13,029	19,341	14,795	900	28.4	.....	19,341	641	15,436	213
262.....	a 672.75	180.00	341	60,000	13,066	28,993	20,015	18,654	10,339	5,224	3,000	10.0	.....	10,339	1,259	6,483	308
263.....	a 737.50	326.00	215	96,000	20,639	30,015	24,928	22,479	7,536	-629	1,200	5.4	.....	7,536	1,090	461	476
264.....	a 738.50	250.00	300	90,000	10,722	39,373	28,684	16,608	22,705	15,654	1,000	21.6	\$240	22,945	609	16,263	227
265.....	a 792.50	295.00	373	100,000	21,474	41,808	35,630	25,289	16,519	8,016	2,000	12.9	.....	16,519	1,920	9,436	564
266.....	a 826.00	180.00	194	100,000	9,496	17,651	12,423	10,958	6,693	-972	1,000	5.2	.....	6,693	1,472	500	157
267.....	a 826.25	250.00	212	78,440	16,877	22,386	18,805	17,085	5,301	-1,371	675	4.8	.....	5,301	920	—	196
268.....	a 825.00	142.00	208	92,000	6,849	18,245	9,794	9,501	8,744	1,825	1,200	7.6	500	9,244	791	2,616	147
269.....	a 857.00	306.00	301	59,840	11,787	40,307	34,538	20,395	19,972	14,958	1,200	26.2	.....	19,972	982	15,940	352
270.....	a 920.00	435.00	231	80,150	12,516	37,929	34,188	22,187	15,742	9,255	1,050	15.8	.....	15,742	703	9,958	431
271.....	a 968.00	370.00	265	60,000	16,023	38,327	30,740	25,117	13,210	7,888	700	16.5	.....	13,210	601	8,489	424
272.....	a 1,043.00	350.00	309	83,200	17,659	48,214	37,634	25,719	22,495	15,435	1,200	21.5	.....	22,495	1,238	16,673	468
273.....	a 1,127.25	496.00	266	172,175	25,360	50,045	44,945	36,151	13,894	67	4,000	5.0	.....	13,894	1,281	1,348	750
274.....	a 1,136.25	510.00	294	100,000	32,556	61,632	51,768	38,193	23,439	14,160	1,800	16.3	.....	23,439	982	15,142	774
275.....	a 1,150.50	110.00	159	100,000	9,536	17,071	5,455	8,545	8,526	858	3,000	5.0	.....	8,526	509	1,367	190
276.....	a 1,239.00	640.00	227	117,840	17,543	59,703	51,952	32,669	27,034	17,557	1,000	19.2	.....	27,034	393	17,950	655
277.....	a 1,241.00	680.00	261	200,000	39,118	72,364	62,899	51,832	20,532	3,794	1,000	8.2	.....	20,532	1,443	5,237	641
278.....	a 1,329.50	122.00	193	94,600	6,093	17,999	8,269	10,688	7,311	262	1,000	6.3	600	7,911	1,169	1,431	118
279.....	a 1,459.25	117.00	391	147,000	13,543	27,984	15,935	12,887	15,097	3,859	1,600	9.0	.....	15,097	978	4,837	258
280.....	a 2,778.00	395.00	225	340,725	27,540	101,044	31,535	34,584	67,060	41,281	1,000	17.9	.....	67,060	887	42,168	611
Average....	223.50	69.3	230	22,847	4,271	8,567	6,177	4,856	3,711	1,813	644	10.1	67	3,778	716	2,539	91

a Includes crop land rented out.

TABLE 2A.—Summary of the farm business on each of 268 white-owner farms, Sumter County, Ga., 1913.

Farm No.	Tilled acres.	Acres in cotton.	Yield of cotton per acre.	Real estate.	Other capital.	Total receipts.	Cotton receipts.	Total expenses.	Farm income.	Labor income.	Operators labor.	Per cent return on capital.	Family labor.	Family income.	Total months of labor.
1.....	9.75	6.00	417	\$1,500	\$326	\$472	\$340	\$314	\$158	\$30	\$300	- 7.8	\$100	\$258	19
2.....	20.00	5.00	500	2,525	570	1,084	312	710	374	157	100	- 8.8	.....	374	24
3.....	20.75	10.00	472	5,300	399	980	704	407	573	174	360	3.8	.....	573	16
4.....	21.50	12.00	417	2,300	247	783	683	360	423	245	300	4.8	.....	423	16
5.....	a 22.00	6.00	375	1,380	568	353	325	366	- 13	-149	200	-10.9	175	162	24
6.....	22.75	12.00	250	1,700	607	469	390	328	141	- 27	120	- 9	120	261	28
7.....	23.00	7.00	321	1,200	418	317	270	342	75	- 38	250	-10.8	15	90	13
8.....	24.50	10.00	200	1,500	293	306	264	284	22	- 40	130	- 6.1	20	42	13
9.....	25.00	13.00	233	1,800	301	543	513	217	326	249	280	6.9	10	336	13
10.....	25.50	12.00	208	2,500	395	382	353	136	187	- 16	200	- .4	.....	187	13
11.....	26.50	15.00	200	560	240	449	423	214	235	179	150	10.6	.....	235	12
12.....	27.50	13.00	385	1,500	732	790	684	664	136	- 20	200	- 2.8	.....	136	24
13.....	28.50	20.00	300	2,280	536	978	260	588	390	193	250	5.0	10	400	26
14.....	30.25	22.00	307	1,420	741	900	890	900	0	-151	100	- 4.6	.....	0	28
15.....	30.25	11.00	273	1,600	694	584	420	400	184	23	150	1.5	.....	184	22
16.....	a 30.50	6.50	154	2,500	300	192	110	148	44	-152	200	- 5.6	8	52	13
17.....	a 30.50	8.00	312	1,500	269	411	340	365	46	- 78	150	- 5.9	125	171	20
18.....	32.00	17.00	294	1,990	780	669	637	450	219	95	125	5.3	160	379	23
19.....	35.00	18.00	389	1,000	888	1,166	955	1,020	146	14	100	2.4	.....	146	22
20.....	35.00	16.00	250	2,450	670	591	540	299	292	74	180	3.6	25	317	14
21.....	35.50	15.00	100	5,600	591	289	198	369	- 80	-513	300	- 6.1	50	30	21
22.....	36.00	15.00	267	900	689	608	443	299	309	198	200	6.9	5	314	13
23.....	38.00	12.00	250	3,000	944	728	410	621	107	-169	225	- 3.0	100	207	21
24.....	38.00	13.00	194	1,800	343	676	442	691	15	-165	300	-14.7	300	285	32
25.....	38.00	23.00	261	3,000	372	852	740	582	270	34	100	5.0	.....	270	29
26.....	38.00	8.00	188	2,500	369	1,078	215	496	582	381	300	9.8	10	592	20
27.....	40.00	18.00	222	1,800	430	646	524	356	290	134	100	8.5	130	420	22
28.....	40.00	16.00	281	3,360	358	942	693	322	620	360	240	10.2	.....	620	22
29.....	41.00	18.00	194	2,500	151	846	518	617	229	43	210	7	100	329	17
30.....	a 41.00	8.00	313	1,700	307	390	310	145	245	105	120	6.2	.....	245	12
31.....	44.75	26.00	327	2,500	587	1,292	1,437	767	525	- 309	240	9.2	.....	525	30
32.....	45.00	14.00	214	2,500	524	1,616	437	406	210	- 2	225	- .5	175	385	24
33.....	46.50	20.00	175	3,500	628	1,058	516	508	182	-107	200	- 4	.....	182	28
34.....	47.00	20.00	300	1,800	783	1,058	900	646	412	231	50	14.0	325	757	34
35.....	48.00	11.00	169	1,890	715	838	766	502	336	154	126	8.1	.....	336	27

a Includes crop land rented out.

TABLE 2A.—Summary of the farm business on each of 268 white-owner farms, Sumter County, Ga., 1913—Continued.

Farm No.	Tilled acres.	Acres in cotton.	Yield of cotton per acre.	Real estate.	Other capital.	Total receipts.	Cotton receipts.	Total expenses.	Farm income.	Labor income.	Operators labor.	Percent return on capital.	Family labor.	Family income.	Total months of labor.
36.....	50.00	10.00	233	\$3,375	\$481	\$1,064	\$970	\$831	\$233	—	\$120	2.9	.....	\$233	26
37.....	51.00	27.00	204	4,000	305	903	707	591	382	81	75	7.1	.....	383	28
38.....	54.00	25.00	260	3,100	605	885	1,800	482	403	144	200	5.5	.....	493	24
39.....	55.75	36.00	250	4,500	1,212	2,092	1,280	1,471	621	11	230	4.3	.....	621	42
40.....	57.00	20.00	375	4,200	584	1,212	1,095	1,449	746	411	200	11.4	35	781	32
41.....	58.00	30.00	300	2,000	912	1,449	1,312	1,032	417	213	200	7.4	.....	417	40
42.....	59.25	22.00	300	3,500	718	1,551	1,011	1,729	822	527	180	13.2	130	972	27
43.....	59.25	28.00	446	5,000	1,213	2,422	1,821	1,061	1,361	926	240	19.0	.....	1,361	27
44.....	59.50	14.00	286	12,500	1,576	1,138	637	608	530	—	130	2.1	.....	680	23
45.....	59.50	30.00	250	3,000	1,052	1,432	1,080	638	794	510	300	12.2	45	839	28
46.....	60.00	30.00	270	4,120	488	1,149	1,134	1,216	—	390	500	12.3	.....	—	38
47.....	60.25	35.00	171	4,000	1,200	1,914	1,885	865	1,049	850	150	3.8	.....	1,049	39
48.....	63.25	42.00	262	4,650	928	1,351	1,265	839	512	122	250	4.7	.....	512	34
49.....	64.00	35.00	229	4,000	613	1,207	1,072	983	224	101	100	2.7	.....	224	44
50.....	64.00	48.00	312	5,000	921	2,381	2,276	1,770	611	197	420	3.2	.....	611	40
51.....	65.00	40.00	338	3,300	776	2,057	1,938	997	1,060	775	200	21.1	.....	1,060	36
52.....	66.75	40.00	275	2,670	763	1,540	1,345	951	589	349	150	12.8	.....	589	36
53.....	67.00	41.00	354	2,300	1,444	1,997	1,724	273	273	11	400	3.4	.....	273	43
54.....	68.00	40.00	236	3,000	533	1,319	1,236	963	356	109	550	5.5	15	371	35
55.....	70.00	20.00	250	6,000	1,428	1,160	1,027	1,133	133	387	240	1.4	210	343	43
56.....	a 70.00	12.00	250	1,680	477	465	410	211	254	103	250	.2	10	264	13
57.....	70.50	40.00	100	6,000	754	649	584	624	25	448	120	2.2	.....	25	25
58.....	71.00	30.00	450	4,400	1,848	2,200	2,023	1,093	1,070	670	120	15.8	.....	1,107	39
59.....	71.00	36.00	333	3,000	1,460	2,112	1,719	951	1,161	849	240	20.6	.....	1,161	20
60.....	71.50	40.00	362	3,520	1,621	2,162	2,076	1,398	764	404	480	5.5	.....	1,764	43
61.....	72.25	30.00	250	5,000	1,758	1,291	1,063	891	400	73	200	3.0	.....	580	32
62.....	73.50	24.00	479	8,500	1,714	1,714	1,568	1,431	283	—	150	1.4	180	308	29
63.....	73.75	35.00	257	2,500	908	1,129	1,075	863	266	27	400	2.9	425	691	35
64.....	74.50	34.00	338	3,000	1,511	1,782	1,601	1,155	790	474	400	8.6	.....	790	39
65.....	a 75.00	20.00	200	5,050	422	1,782	1,550	690	92	291	200	2.0	.....	92	33
66.....	75.00	35.00	200	1,500	1,490	977	884	678	299	90	240	2.0	100	399	32
67.....	a 76.75	16.00	188	2,860	721	555	354	482	73	178	180	3.0	.....	73	24
68.....	78.50	43.00	430	8,180	2,401	3,460	2,848	1,619	1,841	1,100	600	11.7	.....	1,841	52
69.....	79.00	45.00	467	9,500	2,892	3,130	2,940	2,427	1,703	164	400	2.4	.....	1,703	52
70.....	79.00	45.00	356	4,500	1,017	2,382	2,302	1,553	829	443	330	8.7	.....	829	49
71.....	79.75	35.00	257	3,000	1,435	1,255	1,110	1,108	147	163	200	1.2	.....	147	35
72.....	a 80.00	18.00	250	4,000	593	1,760	1,590	619	141	181	100	.9	.....	141	30

73	80.00	15.00	400	1,150	1,138	707	720	762	35	125	240	0	150	185	32
74	80.00	36.50	304	2,560	985	1,575	1,350	1,151	43	189	400	1.0	434	440	45
75	80.00	60.00	333	4,736	736	2,834	2,083	1,256	1,578	1,196	300	23.4	.....	1,578	52
76	80.25	23.00	283	6,240	479	1,251	946	878	373	97	150	3.3	120	493	35
77	81.50	50.00	260	2,100	997	1,720	1,594	1,288	432	215	300	4.3	.....	432	40
78	82.75	45.00	233	10,125	1,681	1,605	1,566	1,334	331	495	300	.....	.....	331	42
79	83.50	25.00	240	9,600	1,253	1,451	1,780	1,127	324	436	300	.....	.....	324	44
80	84.00	61.50	190	2,350	472	1,886	1,761	1,345	541	343	200	12.1	.....	541	56
81	86.00	40.00	312	5,600	1,155	1,878	1,699	1,367	511	38	500	.....	180	691	53
82	86.50	40.00	350	2,000	1,135	1,884	1,788	1,445	439	220	400	1.2	.....	439	56
83	87.50	35.00	228	3,000	1,117	1,007	872	746	261	27	240	.....	180	441	41
84	87.50	40.00	400	6,000	1,206	2,494	2,220	1,787	707	203	420	.....	.....	707	50
85	90.00	60.00	183	4,250	971	2,165	1,500	1,490	675	310	50	4.0	.....	675	56
86	90.25	6.00	250	6,120	1,647	1,314	213	1,146	168	376	500	.....	75	243	26
87	90.75	25.00	310	2,350	697	1,114	834	639	175	38	200	.....	75	250	22
88	91.00	50.00	300	10,500	1,559	2,640	2,187	1,672	968	124	200	6.4	200	1,168	52
89	91.75	55.00	209	4,000	1,533	1,651	1,423	1,423	228	159	360	.....	.....	228	53
90	92.50	52.00	202	1,400	1,696	1,529	1,493	1,431	98	119	50	1.6	.....	98	53
91	94.25	17.00	324	10,000	1,404	1,523	783	1,238	285	513	600	.....	.....	285	40
92	94.25	50.00	310	4,900	1,493	2,388	2,234	1,345	1,043	595	450	9.3	.....	1,043	45
93	95.75	45.00	333	10,000	2,193	2,376	2,145	1,408	968	114	250	5.9	.....	968	58
94	96.50	40.00	225	4,350	1,140	1,595	1,364	1,378	217	167	200	.....	200	417	50
95	96.75	46.00	359	7,500	2,124	3,097	2,499	2,061	1,036	362	360	7.0	200	1,236	59
96	96.75	46.00	261	3,705	1,397	2,127	1,732	668	1,459	1,102	600	16.8	300	1,759	32
97	98.00	49.00	235	8,000	1,818	2,067	1,720	1,475	592	95	360	.....	.....	592	52
98	98.00	69.00	471	7,500	1,555	5,457	4,902	3,441	2,016	298	250	2.4	.....	2,016	64
99	98.50	60.00	392	10,445	2,061	3,204	2,796	1,763	1,441	566	300	19.5	.....	1,441	54
100	99.00	32.00	266	10,950	1,456	1,330	1,020	1,879	451	417	400	9.1	.....	451	32
101	100.25	47.00	351	8,500	1,661	3,028	2,516	1,931	1,097	386	180	9.0	.....	1,097	61
102	101.25	25.00	240	7,400	1,920	1,636	1,282	1,354	354	298	600	2.6	.....	354	50
103	101.25	55.00	223	7,500	1,419	2,230	1,968	1,552	678	58	250	4.8	75	753	55
104	102.25	18.75	293	6,940	949	1,517	1,710	782	735	183	180	7.0	15	750	29
105	103.50	31.00	261	3,000	826	1,408	1,012	930	478	210	280	5.2	5	483	40
106	104.50	60.00	425	4,360	2,587	3,755	3,032	2,146	1,609	1,123	500	16.0	.....	1,609	57
107	105.50	10.00	150	13,500	1,944	3,193	2,900	1,499	1,694	613	730	6.2	300	1,994	64
108	103.75	70.00	168	3,560	1,137	2,263	1,880	1,303	960	631	75	18.8	280	1,240	64
109	104.00	60.00	306	4,275	1,289	2,667	2,561	1,988	679	290	400	.....	.....	679	62
110	104.00	60.00	167	3,000	1,626	1,709	1,577	1,065	704	380	300	8.7	75	779	57
111	104.75	60.00	183	4,666	881	1,285	1,270	1,548	263	651	200	8.4	300	37	60
112	107.50	60.00	312	7,750	1,277	3,155	2,863	1,776	1,379	747	600	12.0	.....	1,379	62
113	108.00	60.00	367	12,000	1,746	3,767	2,801	2,397	1,370	468	400	5.6	.....	1,370	57
114	108.50	60.00	331	9,000	1,218	2,904	2,908	2,259	695	20	350	3.4	75	1,770	73
115	104.00	63.00	303	9,000	2,146	3,233	2,730	1,890	1,403	623	500	8.1	100	1,503	60

^a Includes crop land rented out.

TABLE 2A.—Summary of the farm business on each of 268 white-owner farms, Sumter County, Ga. 1913.—Continued.

Farm No.	Tilled acres.	Acres in cotton.	Yield of cotton per acre.	Real estate.	Other capital.	Total receipts.	Cotton receipts.	Total expenses.	Farm income.	Labor income.	Operators labor.	Per cent return on capital.	Family labor.	Family income.	Total months of labor.
116.....	109.25	65.00	346	\$4,200	\$2,105	\$3,495	\$3,116	\$1,871	\$1,624	\$1,183	\$500	17.8	.....	\$1,624	67
117.....	111.00	65.00	231	3,000	1,355	2,125	1,888	1,153	1,972	527	400	9.0	.....	1,422	65
118.....	113.50	65.00	269	8,000	1,689	2,640	2,025	1,120	1,220	441	400	7.4	.....	1,120	63
119.....	116.00	10.00	250	4,300	704	696	317	569	127	223	150	.....	.....	1,402	30
120.....	a 116.00	38.00	342	4,000	964	2,461	1,972	1,081	1,380	—	200	23.8	.....	1,380	38
121.....	117.75	70.00	321	10,000	1,867	2,697	2,250	1,694	1,003	172	150	7.2	150	1,153	67
122.....	118.25	72.00	257	8,000	1,297	2,972	2,891	2,362	610	41	300	3.3	.....	610	68
123.....	118.25	60.00	292	4,500	1,782	3,413	2,455	1,671	1,742	1,302	360	22.0	.....	1,742	56
124.....	119.00	60.00	300	6,400	2,669	3,034	2,493	1,996	1,038	403	480	6.2	.....	1,038	58
125.....	119.50	75.00	227	4,860	1,071	2,234	2,065	2,004	230	—	600	6.2	.....	1,200	70
126.....	120.25	65.00	300	12,000	2,999	3,232	2,700	2,521	711	—	240	3.1	.....	711	63
127.....	121.50	76.00	336	5,000	1,139	3,520	3,788	2,194	1,626	1,196	360	20.6	.....	1,626	71
128.....	122.00	80.00	212	9,000	1,813	2,557	2,313	2,063	494	—	250	2.3	.....	494	66
129.....	123.75	75.00	253	5,160	997	2,960	2,636	1,784	1,776	745	250	15.0	200	1,376	70
130.....	125.00	48.00	271	12,000	2,525	2,113	1,612	1,719	394	—	200	1.3	.....	1,594	76
131.....	a 126.00	90.00	105	11,000	1,006	1,439	1,332	1,317	122	718	360	2.0	240	362	48
132.....	126.25	20.00	200	6,350	1,780	1,156	560	949	207	263	500	—	100	307	39
133.....	130.00	67.00	358	20,000	1,995	3,715	3,644	2,581	1,134	406	500	2.9	.....	1,134	72
134.....	a 130.00	51.00	294	11,250	4,348	2,986	1,986	2,255	731	361	250	3.1	.....	881	59
135.....	130.00	30.00	167	4,500	588	1,100	1,725	678	422	66	50	7.3	.....	422	40
136.....	132.00	23.00	391	9,600	2,735	2,506	1,357	1,593	913	50	800	9	.....	913	60
137.....	133.00	75.00	413	12,025	3,782	5,498	4,898	4,152	1,346	240	500	5.4	.....	1,346	72
138.....	133.00	80.00	300	10,020	1,730	4,069	3,732	2,535	1,534	712	300	10.5	.....	1,534	74
139.....	133.75	80.00	231	7,280	1,889	2,365	2,365	1,886	1,771	129	240	5.8	.....	1,771	69
140.....	134.00	70.00	300	7,000	2,132	3,343	3,168	2,446	897	258	300	6.5	.....	897	81
141.....	a 135.00	55.00	300	10,557	2,226	3,148	2,760	1,961	1,187	292	200	7.7	.....	1,187	60
142.....	a 135.50	25.00	280	10,000	1,047	1,795	910	1,495	300	473	150	1.4	.....	300	41
143.....	135.50	70.00	296	3,338	1,792	2,705	2,349	1,855	850	561	300	13.3	.....	850	67
144.....	135.50	90.00	278	7,000	1,220	3,897	3,756	2,315	1,582	1,007	240	16.8	.....	1,582	84
145.....	138.00	76.00	276	4,500	1,813	3,429	3,281	1,984	1,445	1,003	240	19.1	.....	1,445	63
146.....	139.00	64.00	273	11,375	2,684	2,553	2,389	1,932	921	63	300	4.4	.....	921	73
147.....	a 140.00	71.00	266	4,000	2,318	2,801	2,457	2,130	671	229	300	5.9	.....	671	63
148.....	a 141.00	80.00	188	4,000	1,113	2,556	2,249	2,034	522	164	1,200	—	.....	522	72
149.....	141.00	95.00	263	7,500	3,136	4,384	3,625	3,049	1,335	590	900	4.1	200	1,535	92
150.....	141.00	75.00	380	8,500	2,638	4,355	4,355	3,496	1,839	1,159	1,000	8.4	100	2,039	79

151	142.00	67.00	291	11,475	3,262	4,610	2,825	2,658	1,952	920	600	9.2	1,952	74
152	144.50	70.00	321	10,000	3,612	3,391	3,000	2,388	1,003	50	1,200	—	1,003	87
153	145.25	7.00	643	15,000	1,083	1,640	585	1,077	563	563	200	2.3	1,563	30
154	147.25	40.00	225	10,000	2,029	2,951	1,366	1,104	262	262	600	4.2	1,104	66
155	149.00	65.00	273	7,500	2,847	3,270	2,445	2,055	1,215	491	480	7.1	1,215	69
156	150.00	120.00	167	5,300	2,012	3,280	2,500	2,816	464	—	—	6.4	464	78
157	151.75	100.00	320	9,240	1,844	4,519	4,519	2,531	2,313	1,549	300	18.4	2,313	62
158	154.00	90.00	344	5,000	1,934	4,826	4,225	2,626	2,200	1,715	180	29.1	2,200	82
159	155.00	115.00	222	5,000	1,253	2,446	3,023	2,524	922	482	300	9.9	1,722	96
160	157.75	35.00	257	10,875	1,983	2,104	1,071	1,323	781	46	300	4.1	1,781	33
161	158.00	87.00	328	9,900	2,893	5,460	4,571	3,108	2,352	1,456	500	14.5	2,352	84
162	158.25	112.00	377	14,600	2,240	7,327	6,653	4,566	2,781	1,582	600	9.4	2,781	96
163	160.50	75.00	320	8,000	2,564	4,202	3,596	2,782	1,420	681	300	10.6	1,420	100
164	160.50	117.00	385	16,000	2,504	5,754	5,655	3,726	2,028	733	400	8.8	2,628	82
165	161.00	96.00	224	12,555	1,877	3,393	2,980	2,244	1,149	139	300	5.9	1,249	93
166	161.00	96.00	250	8,840	2,819	3,686	3,330	1,947	1,739	923	240	12.9	1,739	68
167	167.50	90.00	228	13,050	2,089	3,609	3,073	2,323	1,286	226	200	6.5	1,286	87
168	170.00	80.00	344	11,700	4,269	4,900	4,113	2,521	1,379	261	400	6.1	1,379	90
169	170.00	75.00	360	7,750	1,178	4,457	3,580	2,384	2,103	1,478	600	16.8	2,253	74
170	172.00	82.00	268	9,750	3,888	3,299	2,964	2,761	558	417	500	.3	558	100
171	173.00	11.00	227	13,760	1,218	1,406	350	821	585	463	360	1.5	585	31
172	173.00	85.00	506	9,750	1,449	7,722	5,754	5,146	2,576	1,792	300	15.0	2,576	113
173	173.25	53.00	302	8,600	2,367	3,759	2,484	1,627	2,132	1,434	360	17.8	2,132	32
174	175.75	100.00	235	14,100	2,476	3,965	3,734	3,251	714	446	300	8.2	714	86
175	176.25	84.00	185	16,000	3,274	2,612	2,320	2,725	113	1,462	600	3.7	—	104
176	185.00	80.75	269	10,000	3,345	4,407	3,327	2,925	1,482	548	200	9.6	1,482	86
177	186.00	92.00	280	17,800	1,068	2,483	1,840	1,401	1,082	218	100	5.3	1,082	66
178	187.50	75.00	287	18,000	3,221	2,913	2,580	2,681	232	1,253	1,000	—	412	92
179	200.00	120.00	171	10,125	2,899	2,475	2,460	2,202	639	400	400	1.0	273	122
180	202.00	118.00	169	3,750	1,420	3,597	2,900	2,253	1,304	942	400	17.5	1,304	112
181	202.50	63.00	254	12,000	1,362	3,065	2,310	1,973	1,092	155	400	5.2	1,122	64
182	202.75	140.00	375	9,000	2,761	9,154	8,435	6,481	1,850	1,850	600	17.6	2,673	120
183	205.50	135.00	322	17,800	3,279	5,877	5,712	3,973	1,904	428	600	6.2	2,024	113
184	206.75	135.00	316	9,900	3,378	7,470	7,025	5,736	1,734	805	600	10.8	2,134	182
185	208.25	53.00	453	16,840	4,367	8,608	3,743	3,268	5,340	3,856	600	22.4	5,340	92
186	209.00	90.00	467	17,400	2,965	7,255	6,330	3,003	4,232	2,826	1,200	15.0	4,636	76
187	211.75	88.50	627	15,000	7,822	10,492	7,530	6,262	4,230	2,632	500	16.3	4,430	125
188	213.00	120.00	258	12,000	1,980	5,593	4,885	3,242	2,348	1,369	600	12.5	2,348	109
189	215.00	100.00	250	12,000	573	5,103	3,970	4,200	903	23	900	—	3,903	114
190	216.00	40.00	350	7,750	1,179	2,981	2,110	1,698	1,283	658	300	11.0	1,283	42

a Includes crop land rented out.

TABLE 2A.—Summary of the farm business on each of 268 white-owner farms, Sumter County, Ga., 1913—Continued.

Farm No.	Tilled acres.	Acres in cotton.	Yield of cotton per acre.	Real estate.	Other capital.	Total receipts.	Cotton receipts.	Total expenses.	Farm income.	Labor income.	Operators labor.	Percent return on capital.	Family labor.	Family income.	Total months of labor.
191.....	226.00	118.00	246	\$10,440	\$2,322	\$4,889	\$4,230	\$3,437	\$1,452	\$559	\$300	9.0	.....	\$1,452	107
192.....	227.00	172.00	291	25,000	4,286	7,830	7,225	4,692	3,138	1,088	500	9.0	.....	3,138	142
193.....	230.00	135.00	271	13,500	1,511	2,813	1,247	1,727	1,066	35	700	2.6	.....	1,110	50
194.....	230.75	150.00	400	14,000	4,012	9,867	8,700	4,989	4,878	3,617	600	22.6	.....	4,878	140
195.....	234.00	160.00	241	10,000	1,190	5,913	5,394	4,428	1,465	702	600	7.9	.....	1,465	123
196.....	237.50	50.00	280	8,000	1,817	2,895	1,850	1,580	1,315	628	500	8.3	.....	1,315	42
197.....	240.00	180.00	393	23,400	5,994	7,715	7,150	4,797	2,918	790	1,000	6.3	.....	2,918	162
198.....	241.00	133.00	360	18,150	2,641	6,218	5,541	4,189	2,090	574	1,600	6.9	.....	2,090	111
199.....	244.00	113.00	222	30,000	7,901	6,780	3,315	4,457	2,323	330	1,500	12.2	.....	2,323	109
200.....	245.50	150.00	173	10,500	1,127	4,617	3,671	2,116	1,901	1,987	150	13.1	.....	1,901	102
201.....	247.50	160.00	359	15,000	2,883	9,638	8,313	5,985	3,653	2,401	500	17.6	.....	3,653	154
202.....	248.00	64.00	281	17,000	2,341	3,662	2,778	2,224	1,438	84	500	4.8	.....	1,438	67
203.....	250.00	100.00	220	15,150	1,088	4,008	2,920	2,601	1,407	270	200	7.4	.....	1,407	90
204.....	253.25	130.00	185	17,000	3,229	5,405	3,432	3,658	1,717	301	500	6.0	300	2,017	138
205.....	253.50	150.00	310	22,960	3,180	8,057	7,700	3,855	4,202	2,372	500	14.2	.....	4,202	112
206.....	254.50	120.00	188	10,000	4,252	4,085	3,150	3,475	560	438	1,500	6.6	.....	560	120
207.....	256.00	40.00	275	8,520	1,351	3,217	1,513	1,650	1,507	874	300	12.8	.....	1,507	52
208.....	253.50	55.00	195	10,000	1,483	2,117	1,398	1,763	1,354	450	250	9	.....	354	45
209.....	267.00	160.00	188	26,250	3,900	4,855	4,575	3,366	1,489	621	600	3.0	.....	1,489	138
210.....	268.75	92.00	288	21,875	4,305	5,070	3,845	2,909	2,161	328	600	6.0	.....	2,161	120
211.....	272.50	135.00	307	32,250	5,189	8,156	6,501	5,339	2,817	196	1,000	4.8	.....	2,817	151
212.....	278.50	103.00	223	14,540	2,507	4,151	3,220	3,327	1,934	269	500	2.5	.....	924	94
213.....	286.00	110.00	255	23,150	2,354	4,838	3,820	2,955	1,883	98	500	5.4	.....	1,883	79
214.....	289.00	100.00	175	18,000	1,197	2,714	2,100	1,977	1,737	607	100	3.3	.....	737	102
215.....	298.50	180.00	194	7,150	4,062	5,919	5,333	3,711	2,208	1,423	400	16.1	.....	2,208	173
216.....	301.50	220.00	216	25,000	4,577	7,202	7,065	5,356	1,846	224	350	5.1	.....	1,846	118
217.....	308.00	180.00	358	22,500	7,316	12,208	9,675	7,456	4,752	2,665	600	13.9	.....	4,752	231
218.....	311.00	143.00	238	32,000	2,692	5,806	4,842	3,445	2,361	67	600	5.1	150	2,511	132
219.....	311.75	83.00	253	23,120	3,574	4,000	2,625	2,114	1,886	17	500	5.2	.....	1,886	78
220.....	317.25	77.00	370	30,000	2,323	9,508	3,611	5,733	3,775	1,512	900	8.9	.....	3,775	100
221.....	324.00	180.00	261	32,625	5,289	9,506	7,362	5,203	4,303	1,649	1,000	8.7	.....	4,303	168
222.....	333.50	130.00	188	17,412	3,453	5,614	3,779	3,363	2,251	790	700	7.3	.....	2,251	97
223.....	334.00	90.00	217	12,000	2,726	2,859	2,505	1,825	1,034	3	400	4.3	.....	1,034	71
224.....	334.00	200.00	125	29,350	4,378	5,131	3,619	5,198	67	2,428	600	2.0	.....	67	143
225.....	357.00	217.00	396	18,000	7,762	13,056	13,009	8,751	4,305	2,502	800	13.6	.....	4,305	190
226.....	360.00	174.00	218	21,000	5,836	6,442	5,815	5,061	1,381	498	200	4.4	.....	1,381	166
227.....	362.50	125.00	178	13,600	3,901	5,810	3,740	3,070	1,515	576	300	13.9	.....	2,740	112
228.....	372.00	260.00	195	22,800	5,323	6,588	5,806	5,195	1,393	.....	700	2.5	.....	1,393	173

229.....	279.00	175.00	240	15,000	7,716	5,846	5,440	5,543	303	-1,287	750	-2.0	.....	303	138
.....	a 388.50	105.00	343	7,550	4,070	5,329	.....	5,714	2,615	1,802	1,200	12.2	.....	2,615	138
231.....	a 404.50	80.00	156	27,000	3,422	3,741	1,880	2,988	743	-1,387	300	-1.5	.....	743	80
232.....	419.00	300.00	367	30,000	8,906	16,389	15,440	9,768	6,653	1,000	1,000	14.5	.....	6,653	238
233.....	a 431.50	232.00	167	30,000	9,957	7,653	6,075	7,653	2,304	-377	400	5.0	.....	2,304	233
234.....	a 451.00	165.00	348	20,700	4,812	12,089	8,688	5,013	7,076	5,290	600	25.4	.....	7,076	155
235.....	a 453.50	140.00	363	17,675	1,974	10,513	7,850	6,515	3,998	2,623	1,000	15.3	.....	3,998	128
236.....	454.00	270.00	204	32,000	6,859	10,353	8,100	8,974	1,379	-1,341	400	2.5	.....	1,379	246
237.....	460.00	280.00	325	27,500	7,032	15,184	13,175	9,261	5,923	3,506	1,000	14.3	.....	5,923	224
238.....	462.00	330.00	357	37,375	12,368	20,346	19,596	11,978	8,368	3,456	2,000	9.1	.....	8,368	290
239.....	468.00	330.00	314	30,000	5,067	15,873	12,350	12,602	3,271	816	1,500	5.1	.....	3,271	379
240.....	479.00	300.00	183	50,000	6,625	8,407	7,407	4,980	3,477	-	800	4.7	.....	3,477	238
241.....	479.00	300.00	228	27,000	5,870	12,023	10,790	7,648	4,375	2,074	480	11.8	.....	4,375	253
242.....	a 542.00	232.00	280	33,000	7,059	12,559	10,186	9,221	3,338	534	500	7.1	.....	3,338	221
243.....	545.00	270.00	144	17,500	4,351	5,732	4,395	5,166	566	-964	550	.1	.....	566	283
244.....	a 545.00	175.00	229	16,700	4,287	7,533	6,000	4,693	2,840	1,371	800	9.7	.....	2,840	169
245.....	a 548.00	126.00	421	32,000	3,989	9,204	6,360	6,543	2,661	1,142	2,000	1.8	.....	2,661	121
246.....	a 558.25	202.00	238	34,800	4,074	6,620	5,645	5,809	811	-1,910	600	.5	.....	811	204
247.....	a 560.00	360.00	326	48,750	13,185	17,967	16,917	10,637	7,330	2,995	2,000	8.6	.....	7,330	314
248.....	594.50	390.00	141	21,465	3,783	8,360	7,950	5,740	2,620	853	400	8.8	.....	2,620	266
249.....	a 625.50	280.00	325	25,000	11,178	14,092	11,203	10,426	3,666	1,134	1,800	5.2	.....	3,666	296
250.....	a 692.00	450.00	296	58,850	26,391	20,645	19,955	11,501	9,144	3,177	900	9.7	.....	9,144	337
251.....	728.75	495.00	303	82,500	13,754	23,821	23,240	15,095	8,726	1,988	2,000	7.0	.....	8,726	377
252.....	a 733.00	200.00	360	42,000	6,077	13,368	10,328	6,651	6,717	3,352	1,000	11.9	.....	6,717	181
253.....	758.00	400.00	250	55,000	8,814	15,308	13,438	12,248	3,060	-1,407	800	3.5	.....	3,060	375
254.....	772.25	475.00	310	46,410	9,146	24,262	20,892	16,189	8,073	4,184	1,000	12.7	.....	8,073	379
255.....	a 778.00	102.00	289	27,500	3,029	7,726	4,323	4,791	2,935	798	2,500	1.4	.....	2,935	117
256.....	786.00	520.00	337	32,400	17,506	25,270	21,875	17,978	7,292	3,799	980	12.6	.....	7,292	450
257.....	a 850.00	275.00	156	79,750	3,825	8,127	5,620	5,064	3,063	-2,787	600	2.3	.....	3,063	160
258.....	a 854.00	330.00	319	33,000	6,912	17,723	14,982	14,573	3,150	356	1,000	5.4	.....	3,150	279
259.....	a 878.00	350.00	184	30,000	9,349	9,831	7,849	7,258	2,573	239	750	5.5	.....	2,573	256
260.....	a 942.50	425.00	166	46,710	5,129	11,500	9,762	9,134	2,366	-1,263	200	4.2	.....	2,366	324
261.....	a1,014.00	350.00	314	61,600	14,911	18,146	15,187	10,553	7,593	3,637	1,200	11.3	.....	7,593	293
262.....	a1,050.00	390.00	264	63,000	10,060	18,351	15,080	12,298	6,053	3,939	1,000	6.9	.....	6,053	278
263.....	a1,172.00	445.00	233	42,000	5,947	18,218	14,740	11,768	6,450	3,094	900	11.6	.....	6,450	264
264.....	a1,267.50	620.00	284	60,000	11,538	26,517	24,400	18,771	7,746	2,738	1,000	9.4	.....	7,746	469
265.....	a1,300.00	136.00	206	60,000	3,191	8,274	3,932	6,054	2,220	-2,203	1,200	3.2	.....	2,220	159
266.....	a1,628.00	955.00	357	140,000	22,372	55,013	51,704	35,701	19,312	7,946	2,500	10.4	.....	19,312	755
267.....	a1,912.00	200.00	358	100,000	9,163	16,835	9,854	9,465	7,470	-1,171	1,200	5.7	.....	7,470	720
268.....	a2,617.00	905.00	318	200,000	35,708	46,644	38,284	28,352	18,292	1,792	1,000	7.3	.....	18,292	204
Average.....	227.25	102.29	251	14,165	2,863	4,866	3,995	3,201	1,665	474	476	6.2	43	1,708	95

a Includes crop land rented out.

TABLE 1B.—Summary of the farm business on each of 166 colored-tenant farms, Sumter County, Ga., 1918.

Farm No.	Tilled acres.	Acres in cotton.	Yield of cotton per acre.	Ten-ant's total capts.	Ten-ant's cotton re-ceipts.	Ten-ant's total ex-pense.	Ten-ant's labor in-come.	Opera-tor's labor.	Family labor.	Family in-come.	Family living from farm.	Ten-ant's labor income and family living from farm.	Total months of labor.	Land-lord's re-ceipts.	Land-lord's ex-pense.	Land-lord's return on cap-ital.
1.....	53.75	25.00	204	\$1,848	\$1,331	\$1,026	\$822	\$755	\$300	\$560	\$1,352	\$794	40	\$2,400	\$444	16.8
2.....	54.25	35.00	86	310	375	457	82	104	300	30	—52	172	15	4,410	725	15.1
3.....	54.25	35.00	257	2,162	2,073	1,100	1,662	973	600	240	1,302	407	40	5,425	870	14.5
4.....	54.75	20.00	358	522	2,355	1,941	1,106	1,069	600	315	1,421	637	37	4,000	790	16.9
5.....	54.75	35.00	236	2,549	2,218	1,955	1,594	1,505	1,000	100	1,694	339	26	4,200	725	15.6
6.....	55.25	35.00	229	1,861	1,801	801	1,060	1,027	480	240	1,300	262	24	2,762	870	30.4
7.....	55.50	25.00	170	736	781	69	20	240	240	540	609	470	39	4,800	652	12.6
8.....	56.25	31.00	161	1,175	1,048	758	427	345	360	360	787	921	32	2,250	580	23.4
9.....	56.50	28.00	161	632	683	543	259	215	250	150	409	233	32	4,000	725	16.4
10.....	56.50	20.00	250	1,013	862	680	333	281	300	225	558	393	27	8,000	970	11.4
11.....	56.50	30.00	233	1,079	1,792	1,167	635	559	300	696	1,331	492	46	5,000	725	13.1
12.....	57.00	30.00	250	742	1,892	1,850	926	914	300	480	1,446	462	37	4,500	652	11.8
13.....	57.50	33.00	136	896	1,762	540	356	333	150	270	626	214	30	3,200	725	20.9
14.....	57.50	25.00	208	808	1,376	1,205	578	798	300	288	1,086	408	24	4,800	652	12.7
15.....	57.75	30.00	108	1,099	908	686	415	492	400	480	65	391	28	2,400	435	15.3
16.....	58.25	30.00	83	344	473	792	196	220	250	360	164	297	30	3,012	435	12.6
17.....	58.50	30.00	167	689	845	628	348	300	420	200	548	426	22	4,388	725	15.4
18.....	58.50	35.00	157	567	1,140	613	586	546	600	240	826	445	24	4,500	725	11.9
19.....	60.00	35.00	171	1,342	1,267	1,016	582	488	500	450	1,032	659	32	6,000	870	13.1
20.....	60.00	47.00	170	785	1,940	1,041	989	934	360	525	1,514	599	30	2,400	600	22.8
21.....	61.25	25.00	260	722	1,649	1,322	534	1,115	350	240	1,355	237	24	7,500	870	10.7
22.....	61.50	25.00	100	381	267	501	197	224	180	240	43	239	15	2,500	580	43
23.....	61.50	40.00	175	732	2,030	1,861	923	1,107	300	500	1,607	366	32	7,500	580	56
24.....	61.50	35.00	171	524	1,561	1,427	656	868	480	360	1,265	403	36	2,580	609	21.7
25.....	61.75	40.00	225	590	2,428	1,225	1,275	1,234	300	500	1,775	382	38	4,500	725	15.1
26.....	62.00	30.00	117	1,003	553	619	66	136	360	300	224	186	50	4,000	725	17.3
27.....	62.25	25.00	320	1,209	1,937	1,309	628	543	360	600	1,228	371	42	3,780	900	47
28.....	62.50	30.00	208	1,775	1,650	1,043	607	553	360	240	847	433	41	5,175	580	67
29.....	63.25	25.00	200	1,019	1,404	845	919	848	150	264	1,183	624	24	5,000	640	9.9
30.....	64.75	28.00	125	1,120	794	534	419	341	240	120	539	307	24	3,500	495	12.7

31	65.00	30.00	267	1,034	2,358	1,990	1,067	1,291	1,219	300	240	1,531	394	1,613	33	3,900	850	63	20.2
32	68.00	40.00	112	1,059	2,072	1,880	1,717	1,355	281	300	260	615	265	1,546	28	3,500	725	31	19.8
33	68.00	30.00	250	1,170	1,930	1,746	713	1,137	1,055	120	350	1,487	531	1,586	29	4,250	700	105	14.0
34	68.50	45.00	128	1,257	1,331	1,778	845	486	395	360	240	726	143	1,541	34	7,500	785	76	9.5
35	68.50	40.00	150	1,198	1,423	1,277	732	671	587	400	100	771	373	960	26	4,175	725	42	16.4
36	69.00	30.00	133	1,071	1,107	914	511	596	521	480	225	821	261	782	22	4,200	420	49	8.8
37	70.50	40.00	150	1,215	1,066	1,789	1,175	404	15	240	540	580	352	837	41	3,525	870	92	2.2
38	70.50	35.00	214	1,072	1,889	1,789	1,465	404	329	360	500	1,004	381	810	42	7,100	798	58	10.4
39	72.00	35.00	257	1,198	2,409	2,345	1,389	1,020	936	360	784	1,804	779	1,715	47	3,000	725	61	22.1
40	74.75	30.00	414	2,102	2,652	2,538	1,496	1,156	1,009	500	500	1,656	662	1,671	47	7,500	1,450	90	18.1
41	75.00	30.00	117	655	856	634	242	614	568	200	40	654	382	850	14	3,000	580	51	17.6
42	75.75	40.00	93	471	754	479	551	203	135	240	240	443	579	714	24	2,720	522	100	18.2
43	76.75	48.00	167	987	1,770	1,649	1,110	660	591	460	90	750	279	870	37	4,230	1,088	105	24.5
44	78.00	30.00	183	1,226	1,725	1,391	883	807	883	500	325	1,293	1,027	1,850	32	7,850	580	140	8.5
45	79.00	40.00	225	1,807	2,083	1,782	1,249	834	708	500	600	1,139	732	1,440	30	10,400	1,160	91	10.3
46	79.25	35.00	214	1,449	1,565	1,352	1,356	209	108	300	600	809	527	635	37	10,125	1,160	131	10.2
47	80.75	35.00	186	853	1,609	1,536	873	736	676	300	600	1,336	491	1,167	42	3,000	725	79	17.9
48	82.50	35.00	114	1,154	1,020	838	955	65	16	200	450	515	677	661	37	2,500	880	119	18.4
49	82.75	47.00	202	1,506	2,512	2,313	1,334	1,178	1,073	700	40	1,218	453	1,526	37	5,000	1,015	108	18.1
50	83.00	38.00	207	1,068	2,372	2,040	1,332	1,040	565	800	150	1,190	499	1,404	42	5,810	725	79	11.1
51	83.50	48.00	141	1,149	1,406	1,234	1,273	133	53	200	450	583	712	765	51	8,500	1,125	132	11.7
52	85.00	45.00	272	1,581	2,827	2,324	1,558	1,269	1,158	420	450	1,719	612	1,770	50	7,200	1,348	113	17.2
53	85.25	45.00	111	1,151	1,106	804	527	579	498	200	40	619	566	1,064	23	3,250	652	412	7.4
54	87.00	36.00	170	1,351	2,046	1,620	1,268	778	683	480	240	1,018	771	1,454	34	5,600	440	132	5.5
55	87.00	55.00	251	1,994	3,437	3,295	2,546	891	751	480	530	1,421	282	1,033	63	5,220	1,450	76	26.3
56	91.00	47.00	191	2,652	3,187	2,521	1,835	1,352	1,166	480	300	1,652	442	1,608	71	3,040	580	54	14.4
57	91.50	56.00	222	1,254	2,891	2,800	1,875	1,016	928	480	540	1,556	374	1,302	64	6,000	1,450	121	22.2
58	93.50	45.00	233	1,588	2,840	2,360	1,427	1,413	1,302	300	400	1,813	444	1,744	27	6,000	1,305	74	20.5
59	95.75	50.00	160	1,646	3,020	1,908	1,031	1,989	1,874	500	270	2,259	666	2,540	42	4,040	912	46	21.4
60	96.50	60.00	317	1,833	3,811	3,496	2,457	1,354	1,296	500	200	1,854	570	1,866	64	11,650	4,031	1,005	26.0
61	97.00	43.00	209	1,459	1,938	1,818	850	1,088	986	240	480	1,508	745	1,731	36	10,200	1,160	105	10.3
62	97.25	54.00	194	1,415	2,926	2,760	1,728	1,198	1,099	300	400	1,598	496	1,595	55	3,890	870	68	20.6
63	98.25	45.00	200	1,557	2,424	2,064	752	1,672	1,563	600	300	1,972	427	1,990	27	5,940	870	69	13.5
64	98.50	60.00	233	1,558	3,894	3,812	1,934	1,960	1,851	312	516	2,476	730	2,581	47	9,600	1,305	104	12.4
65	98.75	54.00	250	1,316	3,340	3,193	1,277	2,063	1,971	240	135	2,258	470	2,441	43	6,120	1,305	100	19.7
66	20.00	12.00	242	357	612	533	383	229	204	120	96	325	252	456	23	1,000	362	30	33.2
67	20.50	14.00	84	316	174	169	175	—	23	200	40	39	303	280	14	1,762	219	29	10.8
68	21.00	15.00	183	171	580	573	237	343	331	200	20	363	93	424	13	1,100	362	27	30.4
69	22.25	15.00	150	303	422	422	250	172	151	300	30	202	190	341	14	1,380	362	37	23.6
70	24.50	10.00	200	238	360	335	262	98	81	150	120	218	197	278	18	1,250	362	35	26.2

a Includes crop land rented out.

TABLE 1B.—Summary of the farm business on each of 166 colored-tenant farms, Sumter County, Ga., 1918—Continued.

Farm No.	Tilled acres.	Acres in cotton.	Yield of cotton per acre.	Ten-ant's total receipts.	Ten-ant's cotton receipts.	Ten-ant's total receipts.	Ten-ant's income.	Oper-ator's labor.	Family in-labor.	Family living from farm.	Ten-ant's income and family living from farm.	Total months of labor.	Land-lord's capital.	Land-lord's receipts.	Land-lord's ex-pense.	Land-lord's per cent return on capi-tal.		
71.....	25.50	16.00	250	\$730	\$916	\$348	\$589	\$538	\$360	\$15	\$604	\$819	16	\$1,680	\$450	\$35	24.7	
72.....	25.50	15.00	300	387	809	239	634	607	300	180	814	931	24	2,600	954	260	26.7	
73.....	25.75	14.00	102	320	375	343	32	10	240	160	192	181	19	2,160	203	37	7.7	
74.....	26.00	12.00	206	282	575	298	277	257	300	90	367	353	19	1,560	290	34	16.4	
75.....	26.75	18.00	97	505	389	390	—	36	200	90	89	207	19	2,160	375	10	16.9	
76.....	27.00	14.00	250	510	957	370	674	638	200	80	754	991	16	1,260	290	32	20.5	
77.....	28.25	14.00	110	244	238	188	50	36	300	50	100	213	249	14	960	290	28	27.3
78.....	28.75	14.00	143	584	467	271	196	155	360	20	216	275	13	2,000	290	35	12.8	
79.....	29.00	18.00	194	593	1,154	269	885	843	175	80	965	230	1,072	16	1,085	290	75	19.8
80.....	29.00	12.00	375	907	1,192	668	991	928	300	160	1,151	629	21	2,000	435	45	19.5	
81.....	29.50	14.00	179	316	673	369	304	282	160	240	544	238	24	3,000	362	46	10.5	
82.....	29.75	19.00	138	108	693	647	354	339	360	90	429	112	443	18	1,565	245	47	12.7
83.....	30.50	23.00	152	425	1,061	964	478	583	360	175	758	187	740	22	2,000	290	30	13.0
84.....	30.50	13.00	256	497	794	732	244	550	200	75	625	322	837	15	1,850	348	59	15.6
85.....	31.25	17.00	212	616	1,084	955	782	302	420	312	614	107	366	25	3,125	330	15	10.1
86.....	32.00	20.00	238	707	1,311	1,244	497	814	765	480	934	292	1,057	21	2,400	420	59	15.0
87.....	32.25	20.00	175	623	726	433	303	259	150	160	463	125	384	21	4,000	435	52	9.6
88.....	32.50	16.00	188	368	853	412	441	415	300	60	501	286	701	22	2,100	250	37	10.1
89.....	33.25	18.00	139	250	612	608	233	379	361	120	499	135	496	20	3,400	290	35	7.5
90.....	34.00	18.00	175	630	771	735	351	420	250	75	495	378	754	17	3,400	334	47	8.4
91.....	34.00	20.00	165	657	886	737	290	596	300	100	696	318	868	18	2,160	362	31	15.3
92.....	34.50	18.00	139	254	551	473	338	213	250	140	353	307	502	19	2,100	392	34	17.0
93.....	34.75	18.00	111	215	450	382	196	181	125	108	304	303	484	18	2,376	290	35	10.7
94.....	34.75	25.00	143	665	950	916	284	666	600	80	746	241	867	16	2,550	280	27	9.9
95.....	35.25	25.00	144	717	960	913	443	517	465	240	607	307	772	18	2,700	362	36	12.1
96.....	35.50	18.00	194	523	1,057	954	389	668	240	212	880	305	936	20	1,440	290	14	19.2
97.....	36.00	18.00	194	407	998	988	482	516	488	500	147	663	389	17	1,600	290	41	15.6
98.....	36.00	28.00	239	359	1,868	970	898	873	360	615	1,513	295	1,167	32	1,890	358	55	16.0
99.....	36.25	15.00	116	242	264	536	—	277	360	180	80	223	54	2,160	290	41	11.5	
100.....	36.25	12.00	125	544	252	321	152	114	360	180	332	593	707	20	1,110	248	23	20.3

101.....	36.25	16.00	250	640	1,108	889	643	465	420	360	360	825	355	775	37	3,700	435	46	10.5
102.....	36.50	20.00	236	775	1,405	1,336	571	834	780	600	210	1,044	382	1,162	26	2,600	377	69	11.8
103.....	37.00	20.00	200	445	1,140	1,029	272	868	837	360	40	908	192	1,029	15	2,000	377	49	16.4
104.....	37.25	20.00	168	354	930	832	465	440	25	250	715	332	772	772	23	1,900	348	35	16.5
105.....	37.50	18.00	222	1,005	968	855	547	421	351	480	200	621	373	724	24	2,280	450	52	17.4
106.....	38.25	20.00	125	803	1,000	791	379	621	565	250	50	671	395	960	15	2,000	125	63	3.1
107.....	38.75	26.00	173	249	1,257	1,254	607	650	633	250	320	970	193	826	28	2,900	362	27	11.6
108.....	39.25	20.00	125	618	581	519	154	427	384	240	.....	427	236	620	14	1,500	290	38	16.8
109.....	40.00	27.00	148	608	969	770	242	727	684	240	.....	727	345	1,029	14	2,050	580	33	26.7
110.....	40.50	24.00	107	1,035	764	741	679	85	13	240	320	405	470	483	28	2,025	580	43	26.5
111.....	40.50	30.00	167	346	940	940	741	199	175	360	250	449	60	235	24	3,880	870	22	21.9
112.....	41.50	25.00	120	528	656	634	338	301	360	72	410	360	270	571	16	1,522	362	28	21.9
113.....	41.75	24.00	192	1,295	1,978	1,888	1,177	801	710	480	680	1,481	388	1,098	47	2,088	435	27	19.5
114.....	42.00	20.00	282	406	914	1,769	683	538	510	150	40	378	319	829	16	1,410	364	78	20.3
115.....	42.00	20.00	250	644	1,205	1,150	641	564	519	200	200	764	469	988	22	2,100	435	54	18.1
116.....	42.25	20.00	300	615	1,273	1,233	888	385	342	480	45	430	210	552	23	4,000	725	53	16.8
117.....	42.50	25.00	100	392	1,670	1,586	461	209	182	480	250	459	307	489	22	2,550	290	32	10.1
118.....	43.50	27.00	111	201	816	780	271	545	531	312	780	645	367	898	17	6,420	290	42	3.9
119.....	44.50	30.00	242	1,088	1,970	1,848	763	1,207	1,131	350	400	1,607	380	1,511	32	4,181	652	96	13.3
120.....	45.75	20.00	100	589	476	338	383	93	52	200	200	293	511	563	22	2,000	290	65	11.2
121.....	46.50	30.00	200	1,149	1,869	1,574	499	1,370	1,290	480	224	1,594	324	1,614	28	2,425	580	24	22.9
122.....	47.00	30.00	167	511	1,420	1,284	947	473	437	300	480	1,953	576	1,013	36	3,000	442	106	11.2
123.....	48.25	25.00	224	1,569	1,401	1,321	582	819	709	300	120	839	517	1,226	19	3,000	725	45	22.7
124.....	49.00	21.00	190	1,101	1,100	949	796	304	227	300	396	700	441	668	32	2,310	362	53	13.4
125.....	49.25	23.00	109	604	812	488	238	574	532	240	20	594	236	768	16	1,970	334	54	14.2
126.....	49.50	26.00	173	805	955	860	898	57	1	480	180	237	446	447	30	3,090	750	44	22.8
127.....	50.00	25.00	280	1,317	1,489	1,486	1,002	487	395	360	200	687	440	835	32	5,200	725	70	12.6
128.....	50.25	30.00	160	568	878	767	444	434	390	300	105	539	552	942	19	4,080	870	69	19.6
129.....	51.25	30.00	233	568	1,576	1,566	740	836	796	400	75	911	318	1,114	26	3,120	725	75	20.8
130.....	53.50	33.00	424	1,182	4,112	3,752	1,717	2,395	2,312	400	864	3,259	441	2,753	64	4,800	840	54	16.4
131.....	99.00	53.00	125	583	1,752	1,727	721	1,031	990	360	200	1,231	196	1,186	22	5,940	725	58	11.2
132.....	100.75	48.00	125	1,192	1,593	1,531	947	646	563	75	525	1,171	552	1,115	33	2,625	525	45	18.3
133.....	101.75	28.00	260	1,478	1,701	1,207	911	567	488	360	420	987	672	1,250	27	11,250	1,160	168	8.8
134.....	106.00	68.00	206	1,408	4,132	3,412	2,047	2,085	1,986	360	360	2,445	545	2,531	63	8,100	1,160	79	13.3
135.....	107.50	66.00	175	1,584	2,740	2,571	1,143	1,897	1,486	400	720	2,317	599	2,088	51	4,360	1,088	123	22.1
136.....	109.00	75.00	227	1,760	4,045	4,040	2,264	1,751	1,658	960	840	2,621	285	1,923	70	6,540	1,305	67	18.9
137.....	109.00	75.00	214	1,432	3,238	3,178	2,579	1,659	1,557	300	280	1,939	248	1,805	42	5,040	1,688	67	19.9
138.....	112.25	75.00	200	1,380	4,237	3,114	2,746	2,857	2,067	500	120	2,311	307	2,394	57	7,000	1,450	150	18.6
139.....	113.50	82.00	249	1,546	3,753	3,537	1,776	1,857	1,849	400	40	1,997	103	2,352	64	10,912	1,015	54	8.8
140.....	113.50	60.00	266	3,523	5,110	4,314	2,542	2,568	2,321	480	650	2,568	1,016	3,337	59	15,188	1,100	128	6.8

TABLE 1B.—Summary of the farm business of each of 166 colored-tenant farms, Sumter County, Ga., 1918—Continued.

Farm No.	Tilled acres.	Acres in cotton.	Yield of cotton per acre.	Ten-ant's total capital.	Ten-ant's total receipts.	Ten-ant's total cotton receipts.	Ten-ant's total expense.	Ten-ant's total income.	Ten-ant's labor in- come.	Opera- tor's labor.	Family labor.	Family in- come.	Family living from farm.	Ten-ant's labor income from farm.	Total months of labor.	Land- lord's capital.	Land- lord's receipts.	Land- lord's ex- pense.	Land- lord's per cent return on cap- ital.
141.....	116.25	42.00	112	\$246	489	\$284	\$995	— \$506	— \$523	\$300	\$320	— \$186	\$447	— \$76	28	\$9,635	\$1,624	\$168	15.1
142.....	117.00	72.00	194	1,565	2,811	4,380	2,202	600	—	1,000	1,200	1,800	885	1,354	75	6,675	1,450	192	20.0
143.....	118.25	72.00	227	2,089	4,555	4,380	3,660	1,495	1,349	1,000	1,640	2,135	546	1,895	69	10,000	1,187	202	9.8
144.....	118.50	60.00	216	2,125	4,574	3,150	2,069	2,505	2,356	350	550	2,055	981	3,337	61	10,000	1,305	171	11.3
145.....	118.75	60.00	200	1,674	3,194	3,001	1,363	1,831	1,714	300	640	2,471	529	2,243	44	5,344	1,100	82	20.2
146.....	122.50	80.00	188	2,582	4,188	3,858	1,808	2,380	2,199	600	450	2,830	888	3,087	60	9,350	1,305	123	12.6
147.....	125.50	75.00	160	2,323	3,578	2,984	2,382	1,196	1,033	720	120	1,316	226	1,259	55	5,020	870	101	13.3
148.....	127.00	80.00	212	4,133	3,891	3,515	2,737	1,094	1,865	600	175	1,269	265	1,070	84	9,325	1,608	125	16.2
149.....	129.75	60.00	225	2,302	3,754	3,401	1,152	2,062	1,841	600	770	2,772	508	2,349	37	8,690	1,100	152	12.5
150.....	130.50	70.00	157	1,868	2,879	2,697	2,220	639	528	360	400	1,119	522	1,030	80	6,325	1,160	87	16.4
151.....	131.00	80.00	119	1,570	1,915	1,849	1,474	441	331	600	600	1,041	515	846	32	13,500	1,450	124	9.8
152.....	137.00	65.00	138	1,106	2,358	2,119	1,436	922	845	360	800	1,722	859	1,704	52	7,800	1,015	91	11.8
153.....	138.00	75.00	200	2,817	3,637	3,410	3,220	417	220	600	900	1,317	665	885	77	13,000	1,885	124	13.5
154.....	142.50	65.00	119	950	1,126	917	1,406	—	—	360	210	1,24	571	170	58	12,250	1,812	108	13.4
155.....	143.50	62.00	180	1,291	3,308	2,995	2,610	698	608	100	540	1,238	632	1,240	66	7,000	1,015	242	11.0
156.....	148.25	80.00	236	1,496	5,526	5,392	2,071	3,455	3,350	1,200	840	4,295	870	4,220	71	12,900	1,015	118	6.9
157.....	148.75	76.00	210	2,705	4,461	4,223	2,126	2,335	2,146	400	800	3,135	1,022	3,168	64	8,050	1,450	188	15.7
158.....	151.50	78.00	147	1,349	3,191	3,030	1,666	1,525	1,431	300	680	2,205	583	2,014	60	4,900	1,015	138	17.9
159.....	173.75	75.00	213	1,213	3,932	3,764	2,666	1,326	1,241	300	210	1,536	432	1,673	62	7,200	1,740	91	22.9
160.....	176.25	40.00	162	1,401	1,890	911	878	1,012	914	450	300	1,312	663	1,577	25	14,000	1,305	295	7.2
161.....	185.25	125.00	212	2,493	8,355	8,169	3,067	5,288	5,113	600	200	5,488	442	5,555	77	9,262	1,450	84	14.7
162.....	191.00	160.00	204	2,334	4,647	4,311	3,405	1,079	1,079	600	690	1,982	634	1,713	108	20,158	2,739	223	12.8
163.....	193.75	120.00	169	1,905	6,359	5,181	2,656	2,703	2,570	360	720	3,423	488	3,058	70	8,000	1,740	130	20.1
164.....	239.00	145.00	150	3,248	6,886	5,493	4,482	2,177	2,177	480	345	2,749	861	3,038	116	20,550	2,030	260	8.6
165.....	243.00	45.00	233	4,792	5,379	3,902	2,513	2,866	2,531	400	700	3,566	928	3,459	61	12,000	500	260	2.0
166.....	274.75	90.00	194	1,884	6,338	5,805	4,427	1,911	1,779	300	.....	1,911	378	2,157	80	12,240	1,935	213	14.1
Average...	72.85	37.81	190	1,065	1,899	1,702	1,056	843	768	367	307	1,150	434	1,202	36	4,991	789	86	15.5

a Includes crop land rented out.

TABLE 2B.—Summary of the farm business of each of 186 colored-tenant farms, Sumter County, Ga., 1913.

Farm No.	Tilled acres.	Acres in cotton.	Yield of cotton per acre.	Tenant's total capital.	Tenant's total receipts.	Tenant's cotton receipts.	Tenant's total expenses.	Tenant's farm income.	Tenant's labor income.	Operator's labor.	Family labor.	Family income.	Total months of labor.	Land-lord's capital.	Land-lord's receipts.	Land-lord's expenses.	Land-lord's net return on capital.
1.....	20.25	12.00	250	\$241	\$370	\$271	\$188	\$182	\$165	\$200	\$30	\$212	15	\$750	\$120	\$15	14.0
2.....	21.00	11.00	273	403	453	345	307	146	118	200	100	246	20	750	100	16	11.2
3.....	23.00	12.00	167	279	314	250	202	112	92	180	75	187	18	2,220	300	30	16
4.....	24.25	18.00	167	182	296	270	154	142	129	200	20	162	14	2,550	120	13	19.4
5.....	25.25	14.00	214	197	277	270	136	141	127	120	40	181	16	900	112	15	10.8
6.....	25.25	20.00	188	267	356	330	182	174	155	120	25	199	14	758	144	8	17.9
7.....	26.00	19.00	289	108	756	584	301	455	447	240	95	550	20	2,300	180	26	6.7
8.....	27.00	19.00	132	109	287	245	228	59	51	75	65	124	18	900	126	12	12.7
9.....	23.25	17.00	294	232	566	581	458	78	62	120	200	278	28	900	120	14	11.8
10.....	27.75	20.00	225	443	464	456	413	51	20	200	150	201	25	1,110	156	8	13.3
11.....	28.00	17.00	176	217	287	280	224	63	48	200	50	113	16	4,200	115	21	2.2
12.....	23.00	17.00	132	84	255	191	155	100	94	200	25	125	14	1,000	122	25	9.7
13.....	18.00	18.00	167	208	205	205	132	73	58	175	101	73	14	630	195	12	29.0
14.....	28.25	20.00	188	179	448	377	273	175	162	120	101	279	26	875	110	12	11.2
15.....	29.00	20.00	180	158	404	380	298	106	95	120	75	181	18	700	106	40	9.4
16.....	29.00	18.00	412	423	902	788	400	502	472	170	160	682	28	1,190	194	17	14.9
17.....	29.25	25.00	455	306	263	1,203	617	646	625	180	201	847	30	1,200	240	30	17.5
18.....	29.25	25.00	100	165	188	170	275	87	90	144	68	201	17	1,300	180	8	11.5
19.....	29.50	20.00	220	189	415	415	414	—	—	150	20	—	21	1,450	210	37	12.1
20.....	29.67	20.00	200	540	459	430	278	181	143	80	30	211	16	1,600	120	11	6.8
21.....	29.75	16.00	188	428	276	242	217	59	29	105	50	109	16	900	132	6	14.0
22.....	30.00	20.00	225	57	583	532	370	213	209	130	130	343	24	900	130	6	13.8
23.....	30.00	20.00	202	294	442	432	215	207	246	200	35	302	16	1,000	135	35	10.0
24.....	30.25	17.00	206	408	340	340	224	116	87	300	20	136	14	1,125	120	16	9.2
25.....	31.50	18.00	222	195	307	298	196	111	97	250	50	161	17	4,000	220	25	4.9
26.....	31.50	18.00	139	244	254	202	142	112	95	100	100	132	15	558	130	12	21.2
27.....	31.50	21.00	214	96	431	396	344	87	80	150	150	237	22	960	216	7	21.8
28.....	31.50	20.00	325	225	760	711	253	507	491	150	25	532	18	1,700	114	36	4.6
29.....	31.75	20.00	175	229	372	335	272	100	84	300	125	225	22	1,080	149	8	13.0
30.....	32.00	20.00	250	184	858	599	509	329	316	250	80	409	20	7,000	125	60	.9
31.....	32.00	18.00	181	199	382	375	197	185	171	192	67	252	18	1,050	30	7	2.2
32.....	32.00	23.00	121	294	344	301	191	153	132	150	60	213	17	1,470	130	16	7.8
33.....	32.00	20.00	150	304	253	228	139	94	73	134	40	134	17	1,000	188	17	17.0
34.....	32.00	20.00	139	82	313	252	225	98	82	110	13	101	14	600	199	15	30.7
35.....	32.25	21.00	214	298	435	435	267	168	147	300	25	193	15	1,200	180	28	12.7

TABLE 2B.—Summary of the farm business of each of 186 colored-tenant farms, Sumter County, Ga., 1913—Continued.

Farm No.	Tilled acres.	Acres in cotton.	Yield of cotton, per acre.	Tenant's total receipts.	Tenant's cotton receipts.	Tenant's total ex-penses.	Tenant's farm income.	Tenant's labor income.	Opera-tor's labor.	Family labor.	Family income.	Total months of labor.	Land-lord's capital.	Land-lord's receipts.	Land-lord's ex-penses.	Land-lord's per-cent return on capital.
36.....	32.50	20.00	275	\$610	\$591	\$281	\$329	\$311	\$192	\$100	\$429	20	\$1,425	\$169	\$25	10.1
37.....	33.00	22.00	118	339	299	289	50	28	144	153	293	21	1,550	196	13	9.9
38.....	33.00	20.00	225	549	501	278	271	253	300	80	351	20	1,200	136	18	12.3
39.....	33.25	20.00	262	449	689	291	412	351	392	95	507	20	1,750	98	18	4.6
40.....	33.50	20.00	150	308	308	250	58	50	200	.....	58	19	7,125	125	59	.9
41.....	33.50	21.00	167	317	303	270	47	34	150	110	157	22	680	120	17	15.2
42.....	33.50	18.00	175	372	360	236	136	119	150	75	211	19	1,080	120	19	9.4
43.....	33.50	18.00	138	174	429	271	211	206	200	60	278	17	2,100	120	29	4.3
44.....	33.50	25.00	200	295	589	580	357	336	156	80	437	20	1,369	150	69	5.9
45.....	34.00	20.00	150	248	304	257	20	3	125	50	70	16	1,750	150	20	7.4
46.....	34.50	25.00	180	365	365	439	- 74	- 89	180	171	97	24	1,200	220	19	16.8
47.....	34.50	25.00	120	326	285	256	99	76	160	25	124	15	1,750	150	13	7.8
48.....	34.50	20.00	150	402	302	286	114	86	120	20	134	15	1,225	123	14	8.9
49.....	34.50	25.00	200	324	588	260	421	398	125	100	521	20	1,280	130	27	8.0
50.....	35.00	25.00	91	157	147	269	- 112	- 116	240	100	- 12	22	1,600	138	15	7.7
51.....	35.00	22.00	114	76	251	142	18	13	144	70	88	17	2,081	176	22	7.4
52.....	35.00	19.50	179	330	355	305	214	118	150	20	161	15	700	180	11	24.1
53.....	35.00	20.00	250	101	692	552	435	428	150	25	460	14	1,350	115	19	7.1
54.....	35.25	27.00	120	477	309	267	76	43	200	50	126	16	1,265	150	36	9.0
55.....	35.25	27.00	167	257	466	169	297	279	120	.....	297	13	1,444	150	77	5.1
56.....	35.50	24.00	247	336	625	546	181	157	125	200	381	29	1,450	240	77	11.2
57.....	35.50	24.00	146	77	458	336	223	218	240	60	283	17	1,200	150	25	10.4
58.....	35.50	25.00	120	353	357	302	136	111	200	30	166	16	3,200	130	20	3.4
59.....	36.00	23.00	283	356	732	632	501	231	200	180	371	22	1,200	180	21	13.2
60.....	35.00	22.00	279	173	731	712	405	364	190	125	501	22	1,960	152	29	6.3
61.....	36.00	25.00	200	471	658	544	379	346	144	59	438	18	1,620	150	24	7.8
62.....	36.00	22.00	364	1,088	1,022	755	333	322	300	375	708	37	1,480	305	20	19.3
63.....	36.25	22.00	133	398	272	244	51	23	150	130	181	22	1,225	144	15	10.5
64.....	36.25	25.00	180	153	470	337	133	122	144	.....	303	16	1,200	150	14	11.3
65.....	36.50	25.00	180	342	484	452	104	80	144	200	334	29	1,250	115	12	8.2
66.....	37.00	24.00	167	122	522	377	177	168	150	163	340	25	1,350	124	15	8.1
67.....	37.25	26.00	192	323	502	206	302	279	500	50	352	16	1,350	162	32	9.6
68.....	38.00	25.00	260	136	708	680	373	325	125	50	385	18	2,000	180	22	7.9
69.....	38.00	25.00	200	222	548	438	291	241	80	135	392	22	1,250	220	13	16.6
70.....	38.50	20.00	250	414	597	468	76	47	240	75	151	26	2,250	260	18	10.8

71	38.50	25.00	165	273	528	491	303	225	206	100	100	325	116	13	7.4
72	39.00	28.00	170	342	475	444	334	141	117	156	110	251	168	20	12.3
73	39.00	28.00	170	320	381	372	388	183	200	150	150	243	125	18	13.4
74	40.00	30.00	267	357	570	811	398	452	455	200	151	633	188	22	9.5
75	40.50	24.00	271	449	766	735	507	259	228	200	200	459	182	31	6.5
76	41.00	30.00	140	661	513	438	246	267	221	225	55	322	120	16	3.2
77	41.00	30.00	233	257	812	705	456	354	336	200	40	394	300	85	12.0
78	41.75	25.00	120	251	305	290	224	81	63	180	35	146	130	82	7.2
79	42.00	30.00	291	456	919	791	473	446	414	180	140	586	200	93	11.5
80	42.50	32.00	211	46	814	770	323	491	458	144	65	556	144	26	6.8
81	43.50	30.00	250	128	576	576	418	158	149	100	75	233	324	20	9.8
82	44.00	28.00	214	314	634	588	507	137	105	144	60	187	300	77	12.4
83	44.50	36.00	181	480	738	738	607	131	97	150	75	206	180	25	8.3
84	44.50	25.00	240	311	646	645	395	251	229	192	110	361	200	23	17.2
85	44.75	30.00	142	488	319	215	416	97	131	150	150	53	360	38	7.2
86	45.00	22.00	91	305	276	174	177	99	78	150	20	119	120	17	2.8
87	45.25	27.00	167	272	646	531	160	486	467	192	48	534	125	40	11.3
88	45.50	27.00	241	269	778	651	430	348	329	200	200	548	276	16	18.8
89	46.00	33.00	197	430	661	630	396	265	235	200	175	440	300	21	11.2
90	46.00	37.00	346	312	1,860	661	563	1,297	1,275	250	120	1,417	172	15	7.4
91	46.25	24.00	125	237	328	275	249	79	62	500	100	179	158	15	7.2
92	47.00	35.00	329	338	1,184	1,182	725	459	435	150	250	709	375	28	28.9
93	47.50	28.00	163	207	574	515	404	170	156	150	200	370	302	31	6.2
94	48.50	32.00	203	372	728	663	397	331	305	200	30	361	240	17	20.5
95	48.75	35.00	143	221	488	460	477	11	4	240	100	111	248	30	3.0
96	49.00	25.00	260	432	922	785	1,143	221	251	180	270	49	200	10	8.8
97	52.00	37.00	107	410	376	219	390	142	171	150	150	8	304	27	18.3
98	52.25	33.00	333	216	248	1,268	840	536	521	200	395	931	302	43	6.6
99	53.50	30.00	250	479	805	765	448	357	323	300	20	377	285	16	11.9
100	54.00	40.00	175	387	797	782	518	279	252	300	200	479	260	11	15.4
101	55.00	37.00	267	587	957	957	567	390	349	170	128	518	325	52	6.8
102	55.00	34.00	265	688	1,344	911	625	719	671	150	200	919	360	25	16.0
103	55.25	40.00	162	584	806	576	779	173	214	300	160	13	275	33	10.6
104	55.25	40.00	175	197	816	816	428	388	374	150	147	535	120	13	5.9
105	55.25	42.00	179	420	775	752	409	366	337	180	158	524	250	14	10.4
106	55.25	40.00	262	451	1,346	1,304	780	566	534	180	350	916	262	28	5.8
107	57.00	39.00	256	155	848	848	554	377	366	150	174	551	411	5	14.2
108	57.50	40.00	250	448	955	930	744	211	180	192	232	443	312	47	13.9
109	58.00	40.00	125	402	415	395	619	204	232	75	250	46	390	13	20.9
110	58.25	25.00	220	169	477	424	532	75	87	150	200	125	300	123	7.4
111	58.25	40.00	225	267	1,077	1,026	631	446	427	200	200	646	225	19	7.8
112	59.00	36.00	244	566	1,053	987	683	320	320	120	120	480	275	42	9.3
113	59.00	35.00	214	305	1,038	743	531	507	486	240	129	636	319	33	6.5
114	59.25	45.00	140	349	641	587	466	175	151	150	160	335	262	36	17.4
115	59.50	40.00	175	329	783	705	587	196	173	160	200	396	260	20	10.3

TABLE 2B.—Summary of the farm business of each of 186 colored-tenant farms, Sumter County, Ga., 1913—Continued.

Farm No.	Tilled acres.	Acres in cotton.	Yield of cotton per acre.	Tenant's capital.	Tenant's total receipts.	Tenant's cotton receipts.	Tenant's total expense.	Tenant's farm income.	Tenant's labor income.	Operator's labor.	Family labor.	Family income.	Total months of labor.	Land-lord's capital.	Land-lord's receipts.	Land-lord's expenses.	Land-lord's percent return on capital.
116.....	59.50	40.00	288	\$540	\$1,372	\$1,228	\$757	\$615	\$577	\$200	\$150	\$765	37	\$4,151	\$304	\$44	6.3
117.....	59.75	40.00	250	353	1,520	1,516	905	614	589	250	125	739	33	3,100	175	37	6.6
118.....	60.00	35.50	244	544	855	770	512	343	305	200	143	486	36	2,250	360	16	15.3
119.....	60.25	243	233	752	926	877	739	167	114	200	300	467	37	2,250	300	33	11.9
120.....	61.50	40.00	200	249	1,077	851	806	271	254	130	234	505	38	1,320	240	38	15.3
121.....	61.50	35.00	293	611	1,100	1,013	813	287	244	180	60	347	32	3,100	411	15	12.8
122.....	63.50	35.00	382	948	1,310	1,310	333	615	588	250	275	615	12	2,100	260	15	11.7
123.....	64.00	33.00	197	352	753	601	608	145	118	150	420	420	36	1,950	325	92	12.0
124.....	64.50	38.00	258	655	1,045	1,045	405	183	165	240	218	401	30	3,752	352	30	8.5
125.....	64.75	40.00	231	566	867	796	895	—	68	313	465	437	45	1,750	288	12	15.8
126.....	65.00	35.00	229	262	1,011	904	1,001	30	8	300	450	460	44	2,750	245	44	7.3
127.....	65.50	50.00	127	421	1,212	1,032	863	149	320	200	125	474	37	2,000	260	15	12.2
128.....	66.00	37.00	135	452	417	405	457	40	72	150	250	210	32	3,200	325	18	9.6
129.....	66.00	48.00	188	328	862	790	766	96	73	250	250	346	34	3,500	330	34	8.5
130.....	66.75	40.00	162	572	775	648	490	285	245	216	222	507	30	1,600	288	28	16.2
131.....	67.00	44.00	216	258	968	950	634	334	316	240	325	659	38	2,750	275	32	8.8
132.....	67.00	40.00	146	644	1,463	1,336	899	564	519	180	465	1,029	43	4,000	396	30	9.2
133.....	67.50	40.00	198	492	875	849	486	389	355	100	75	464	24	1,400	250	23	16.2
134.....	67.75	35.00	143	400	503	442	482	21	7	144	180	201	27	1,620	230	21	12.9
135.....	67.75	45.00	211	593	1,037	1,034	665	371	329	600	258	629	30	2,250	300	46	11.3
136.....	68.00	40.00	250	962	1,500	1,160	751	749	682	180	416	1,165	44	2,400	230	32	8.2
137.....	68.25	45.00	141	421	687	667	537	150	121	175	200	350	30	3,750	260	38	5.9
138.....	68.50	45.00	200	750	910	895	831	79	27	192	348	427	41	3,500	455	36	12.1
139.....	69.00	47.00	253	434	1,054	1,040	359	695	665	100	20	715	18	1,400	356	20	24.0
140.....	69.50	50.00	290	600	1,744	1,576	644	1,100	1,058	180	300	1,400	36	2,625	360	55	11.6
141.....	70.00	34.00	250	1,101	1,567	875	912	182	105	180	300	482	36	2,700	306	33	10.1
142.....	70.00	57.00	141	667	1,556	1,549	1,096	460	413	144	407	867	49	3,280	382	31	10.7
143.....	71.00	35.00	157	576	679	567	437	242	202	120	150	392	25	4,740	240	21	4.6
144.....	71.00	50.00	210	672	1,101	904	715	386	339	300	686	754	40	3,150	375	50	10.3
145.....	72.00	40.00	288	230	1,335	1,150	928	407	391	144	347	754	40	2,400	450	26	17.0
146.....	72.25	55.00	164	456	977	940	753	224	192	192	305	529	33	2,100	300	26	13.0
147.....	72.50	50.00	140	463	710	678	585	125	93	200	300	425	36	2,570	270	45	8.8
148.....	73.75	50.00	280	546	1,695	1,637	980	735	697	300	500	1,235	34	2,250	300	16	12.6
149.....	74.50	45.00	256	1,210	1,643	1,636	1,106	537	452	200	200	737	36	2,250	175	26	6.6
150.....	75.25	55.00	109	679	1,667	570	535	132	84	200	315	447	33	1,900	240	20	11.6

151.....	77.75	53.00	255	873	2,060	1,464	719	1,341	1,250	400	400	1,741	44	2,800	345	66	10.0
152.....	80.00	49.00	197	433	1,030	904	681	349	1,250	240	125	474	37	3,000	239	21	7.9
153.....	80.50	70.00	121	228	1,012	863	700	316	296	100	100	402	29	3,284	360	168	5.8
154.....	82.00	35.00	154	989	587	449	632	45	114	240	108	63	23	3,800	350	39	4.3
155.....	82.50	55.00	273	920	2,204	1,807	626	1,178	1,114	240	370	1,548	53	3,075	372	33	11.0
156.....	83.00	37.00	297	573	1,438	1,099	670	768	728	240	.....	768	30	4,000	396	30	9.2
157.....	84.00	60.00	208	937	1,607	1,316	493	493	427	300	275	768	50	3,500	385	100	8.1
158.....	84.50	60.00	225	785	1,346	1,188	1,036	310	255	250	25	335	42	4,800	585	41	11.3
159.....	90.00	65.00	223	985	1,880	1,782	1,186	694	625	192	453	1,147	49	3,000	315	36	9.3
160.....	90.75	60.00	308	1,218	1,713	1,603	1,267	448	363	200	270	718	56	4,000	562	66	12.4
161.....	91.50	62.00	143	647	1,007	897	886	121	76	50	250	371	49	4,000	418	35	9.6
162.....	92.50	55.00	255	1,280	1,667	1,008	1,423	356	446	150	500	144	67	3,645	360	59	8.2
163.....	96.00	72.00	278	908	2,634	2,449	1,134	1,500	1,436	180	330	1,830	57	4,200	529	29	11.9
164.....	98.00	70.00	250	580	1,309	1,838	915	994	953	125	370	1,364	49	3,720	510	26	13.0
165.....	100.75	60.00	325	389	2,296	2,060	1,477	819	792	300	200	1,019	62	3,120	450	41	13.1
166.....	102.50	60.00	125	438	757	677	1,152	395	426	180	750	355	62	5,400	345	171	3.2
167.....	109.75	70.00	121	1,153	969	788	1,728	241	160	200	275	516	34	5,600	455	39	7.4
168.....	112.00	80.00	219	547	1,868	1,807	1,123	745	707	200	200	945	46	3,510	250	25	6.4
169.....	112.50	65.00	208	526	1,798	1,437	1,343	455	418	240	350	805	57	5,880	360	41	5.4
170.....	113.25	80.00	225	1,077	2,025	1,962	1,243	752	707	200	300	1,082	53	6,000	530	71	7.6
171.....	115.00	75.00	160	524	1,131	1,099	778	353	316	250	200	553	32	6,000	440	70	6.2
172.....	116.00	72.00	219	758	1,661	1,590	1,670	9	62	100	201	192	68	8,080	600	85	6.4
173.....	116.25	75.00	213	907	2,305	2,079	1,214	1,091	1,028	250	400	1,491	53	2,400	413	26	16.1
174.....	118.25	73.00	257	318	2,319	2,164	1,668	651	629	320	.....	651	55	6,000	480	74	6.8
175.....	119.50	80.00	219	1,151	1,962	1,928	1,203	759	678	300	150	909	48	5,400	627	57	10.6
176.....	119.75	75.00	353	1,692	3,625	3,436	2,157	1,468	1,350	150	840	2,368	93	7,500	460	69	5.2
177.....	127.25	98.00	224	1,392	2,113	2,113	1,271	852	755	192	510	1,352	59	5,000	735	57	11.3
178.....	137.25	90.00	222	1,705	1,945	1,777	1,916	29	90	600	600	629	74	7,500	625	90	7.4
179.....	137.25	90.00	161	607	1,610	1,488	1,193	417	375	250	125	542	43	5,000	440	67	7.3
180.....	138.00	100.00	160	986	2,144	1,835	1,375	769	700	500	350	1,119	61	2,600	275	122	5.9
181.....	144.75	96.00	198	1,038	2,206	2,101	1,711	495	422	300	50	545	71	11,760	480	100	3.2
182.....	149.25	120.00	250	1,701	3,577	3,498	2,308	1,269	1,550	160	397	1,666	92	4,500	585	56	11.8
183.....	181.00	125.00	194	1,338	2,755	2,439	1,736	1,019	925	200	175	1,194	77	5,350	715	81	11.8
184.....	200.75	140.00	193	1,767	2,440	2,440	2,409	337	213	600	15	102	102	24,300	840	63	3.2
185.....	204.25	135.00	230	2,349	3,926	3,761	2,142	1,784	1,620	180	.....	1,784	78	6,440	600	120	7.4
186.....	224.75	155.00	245	2,253	4,812	4,348	3,077	1,735	1,577	200	339	2,074	110	6,800	1,062	107	14.0
Average....	59.19	38.81	209	475	943	854	620	323	290	198	168	491	31	2,719	267	34	10.5

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
20 CENTS PER COPY



UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 1035
Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C.

PROFESSIONAL PAPER

February 17, 1922

THE RED SPIDER ON THE AVOCADO.

By G. F. MOZNETTE, *Assistant Entomologist, Tropical and Subtropical Fruit
Insect Investigations.*

CONTENTS.

	Page.		Page.
Introduction	1	Predatory enemies	9
Economic importance	1	Spraying experiments	11
Nature of injury to foliage	2	Spray rod versus spray gun	13
Food plants and distribution	2	Cultural methods in the grove	14
Description and habits	4	Recommendations	15
Biological data	7		

INTRODUCTION.

The red spider *Tetranychus yothersi* McG. is one of the foremost enemies of the avocado and attacks a number of other plants and fruit trees in Florida. It was recognized by avocado growers as an important enemy of this fruit as early as 1909, and since that time the damage caused by it has become more pronounced each year. This bulletin records the work with this spider during the years 1918 and 1919 and the results of cooperative spraying experiments in connection with the station established by the Bureau of Entomology in 1917 at Miami, Fla., for the investigation of various insect enemies of the avocado and other subtropical fruits characteristic of that region.

ECONOMIC IMPORTANCE.

In groves where the red spider is abundant the trees frequently become defoliated prematurely during the winter season. This generally results in an abnormal development of bloom the following spring and the weakened trees are unable to set and hold a full crop

of fruit. To sustain the bloom and aid in the setting of fruit the older foliage should remain on the trees until a sufficient amount of new growth apparently arising from the inflorescence (fig. 1) has been produced in the spring to take its place.

NATURE OF INJURY TO FOLIAGE.

The red spider punctures the leaves and sucks the contents, forming white spots at the point of attack. As these feeding punctures and

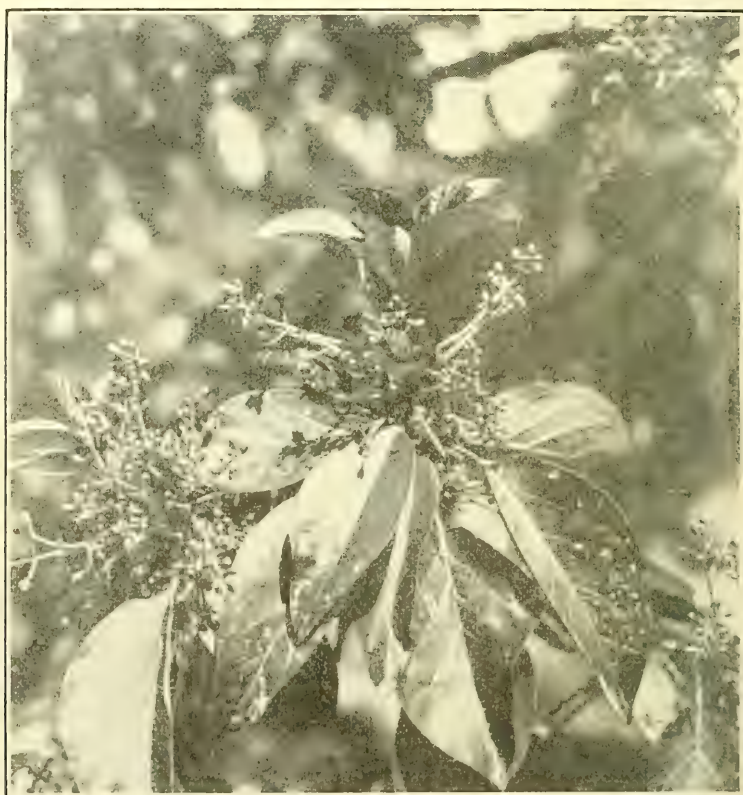


FIG. 1.—Avocado blossom cluster with older leaves which sustain the bloom, and developing new growth.

resultant white spots become more in evidence a gradual burning and reddening of the foliage results, as if scorched by fire (Pl. I, A, B). The foliage so attacked soon falls, giving the tree a naked appearance (fig. 2).

FOOD PLANTS AND DISTRIBUTION.

This red spider was first named and described by E. A. McGregor¹ from specimens on camphor (*Cinnamomum camphora*) leaves sent

¹ MCGREGOR, E. A. FOUR NEW TETRANYCHIDS. In Ann. Ent. Soc. Amer., v. 7, no. 4, p. 355-357, 1914.



A. Heen & Co. Baltimore

THE RED SPIDER OF THE AVOCADO

A, Avocado leaf with characteristic reddening and scorched appearance caused by the red spider; B, Uninjured avocado leaf.



him in 1914 by W. W. Yothers, of Orlando, Fla. The writer has found it attacking both the West Indian and Guatemalan varieties of avocados (*Persea gratissima*), being particularly injurious to the more tender West Indian types. It occasionally causes considerable injury to the mango (*Mangifera indica*) and in many sections of northern Florida to the camphor and Australian silk oak (*Grevillea*



FIG. 2.—Defoliated avocado tree during midwinter, the result of attacks on foliage by the red spider.

robusta), to the foliage of which it imparts the same discoloration that it causes to the avocado. It has also been collected in Florida on a species of eucalyptus (*Eucalyptus* sp.). In addition to these host plants, the writer has at times collected the red spider on *Terminalia arjuna*, *Annona squamosa*, *Cucumis sativus*, and *Leucaorea paniculata* — the latter a plant growing quite commonly in the hammocks of southern Florida.

Mr. E. A. McGregor reports it as attacking also the American elm (*Ulmus americana*) and two other varieties of elm (*Ulmus* spp.), the willow (*Salix* sp.), the white oak (*Quercus alba*), and the pecan (*Hicoria pecan*), at Batesburg, S. C. He records it also on elm (*Ulmus* sp.) from Columbia, S. C., and Laurinburg, N. C. These records indicate a probable wide distribution of this red spider through the South. In Florida the writer has found this species along both the east and west coasts, including Miami Beach, Miami, Biscayne Key, Homestead, West Palm Beach, Florida City, Fort Myers, Bradentown, Oneco, and Winter Haven.

DESCRIPTION AND HABITS.

THE ADULT FEMALE.

In appearance the adult female (fig. 3, *f*) is similar to most red spiders which attack various other crops. It is small, of a rusty red

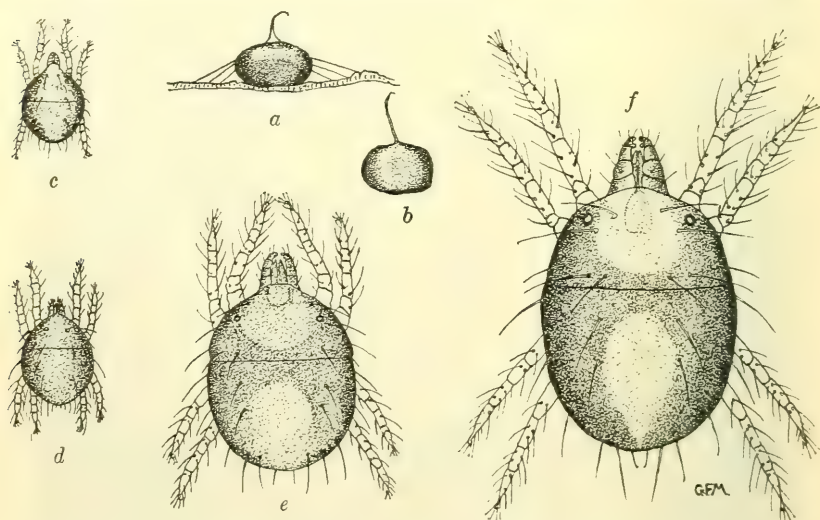


FIG. 3.—The avocado red spider: *a*, *b*, Egg; *c*, larva; *d*, first nymph; *e*, second nymph; *f*, adult female.

color, averaging 0.30 mm. in size. The abdomen joins the cephalothorax, formed by the fusion of the head and thorax, at its full width and extends over the portion to which the posterior pair of legs is attached. The body and legs are covered with bristles.

THE MALE.

The body of the male is slender and pointed toward the tip of the abdomen and is somewhat smaller than that of the female. The legs are slightly darker and longer than those of the female. The eyes are red and somewhat more conspicuous than those of the female. It averages 0.22 mm. in length.

THE EGG.

The egg (fig. 3, *a, b*) is globose in shape, smoky amber in color, and bears a stalk at its apex. Guy fibrils are occasionally seen connecting the egg with the leaf.

The eggs are deposited singly and when the leaf first becomes infested are generally found located along the midrib at the base of the leaf. As the activities of the mites increase with succeeding generations, the eggs may be found scattered over the entire leaf.

The incubation period varies according to the temperature and general climatic conditions. (See Table 1.) During midwinter, with mean daily temperatures between 60° and 70° F., incubation requires from 7 to 11 days. During April and May the incubation period averaged from 4 to 5 days with mean temperatures between 70° and 80° F., in rearing experiments with this species. In hatching, the shell of the egg splits more or less completely around and the larva easily extricates itself. During the height of the red spider season leaves will be observed heavily covered with hatched eggshells which adhere to the leaf and impart to it a whitish cast.

TABLE 1.—*Length of the egg stadium.*

No.	Date deposited.	Date hatched.	Duration.	Mean temperature.	No.	Date deposited.	Date hatched.	Duration.	Mean temperature.
			<i>Days.</i>	<i>° F.</i>				<i>Days.</i>	<i>° F.</i>
1	Oct. 15	Oct. 20	5	78	7	Jan. 21	Feb. 1	11	60
2	Oct. 22	Oct. 26	4	77	8	Feb. 15	Feb. 22	7	70
3	Nov. 8	Nov. 13	5	72	9	Mar. 15	Mar. 20	5	72
4	Nov. 30	Dec. 8	8	70	10	Apr. 1	Apr. 5	4	75
5	Dec. 18	Dec. 25	7	65	11	May 31	June 5	5	76
6	Jan. 1	Jan. 11	10	58	12	July 11	July 15	4	79

THE LARVA.

The newly hatched larva (fig. 3, *c*) is round, very light yellow, possesses six legs, and in size does not exceed that of the egg from which it emerged. It is very delicate, and a marked characteristic is its possession of conspicuous carmine eyes. During the process of development and feeding the young creatures commence to change color. The larva measures 0.17 mm. in length on an average.

As with practically all mites the larva stage is divided into an active and a quiescent period. The former is passed while the larva is feeding and the latter in preparation for the first molt. The time spent in the quiescent period of the larva stage averages in most instances only a few hours. The average length of the larval period is 2.58 days.

TABLE 2.—*Length of the larval stadium.*

No.	Date of hatching.	Date molted.	Duration.	Mean temperature.	No.	Date of hatching.	Date molted.	Duration.	Mean temperature.
			<i>Days.</i>	<i>° F.</i>				<i>Days.</i>	<i>° F.</i>
1	Oct. 18	Oct. 20	2	76	7	Feb. 1	Feb. 4	3	65
2	Oct. 28	Oct. 31	3	77	8	Feb. 22	Feb. 24	2	70
3	Nov. 15	Nov. 19	4	75	9	Mar. 20	Mar. 23	3	72
4	Dec. 10	Dec. 13	3	70	10	Apr. 5	Apr. 7	2	75
5	Dec. 25	Dec. 28	3	68	11	June 5	June 7	2	76
6	Jan. 11	Jan. 15	4	63	12	July 13	July 15	2	79

THE FIRST NYMPHAL STAGE (THE PROTONYMPH).

The first nymphal stage (fig. 3, *d*) differs from the larva in having four pairs of legs instead of three and is slightly increased in size. The extra pair of legs appears behind the last pair of legs of the larva. The segments of the legs become longer, as do likewise the bristles on the body and legs. The color of the body darkens. The abdomen in this stage becomes elongated as compared to the larva. The average length of the protonymph is 0.25 mm.

For the most part the habits of the nymphal stage are similar to those of the larva. As with the larval stage the protonymph stage is divided into an active feeding period and a quiescent period preparatory to molting. The average length for the first nymphal stage is 2.8 days.

TABLE 3.—*Length of the first nymphal stadium.*

No.	Date emerged.	Date molted.	Duration.	Mean temperature.	No.	Date emerged.	Date molted.	Duration.	Mean temperature.
			<i>Days.</i>	<i>° F.</i>				<i>Days.</i>	<i>° F.</i>
1	Oct. 20	Oct. 22	2	76	7	Feb. 4	Feb. 6	2	65
2	Oct. 31	Nov. 3	3	77	8	Feb. 24	Feb. 26	2	70
3	Nov. 19	Nov. 23	4	75	9	Mar. 23	Mar. 25	2	72
4	Dec. 13	Dec. 18	5	70	10	Apr. 7	Apr. 9	2	75
5	Dec. 28	Jan. 1	4	68	11	June 6	June 8	2	76
6	Jan. 15	Jan. 18	3	63	12	July 14	July 16	2	79

THE SECOND NYMPHAL STAGE (THE DEUTONYMPH).

The second nymphal stage (fig. 3, *e*) is similar to the first nymphal stage except that it is much larger and more elongate. In its full-grown condition, however, it resembles more the adult, though the color is not as deep a red. It averages 0.38 mm. in length.

The habits of the second nymphal stage are likewise similar to those of the larva stage. The average length for the second nymphal stage is 2.84 days.

TABLE 4.—Length of the second nymphal stadium.

No.	Date emerged.	Date molted.	Duration.	Mean temperature.	No.	Date emerged.	Date molted.	Duration.	Mean temperature.
			Days.	° F.				Days.	° F.
1	Oct. 22	Oct. 25	3	76	7	Feb. 6	Feb. 10	4	65
2	Nov. 3	Nov. 6	3	77	8	Feb. 26	Feb. 29	3	70
3	Nov. 23	Nov. 25	2	75	9	Mar. 25	Mar. 28	3	72
4	Dec. 18	Dec. 21	3	70	10	Apr. 9	Apr. 12	3	75
5	Jan. 1	Jan. 4	3	68	11	June 8	June 10	2	76
6	Jan. 18	Jan. 24	3	63	12	July 16	July 18	2	79

BIOLOGICAL DATA.

Webbing.—Unlike the majority of red spiders this species does not spin an extensive web and carries on its depredations on the foliage practically unprotected. The only indications of any webbing made by this species are the mere fibrils attached to the apex of the eggs when deposited (fig. 3, a).

Average length of life period.—The length of the life period of the adult mites varies greatly with the season and temperature and possibly other conditions. Experiments on the life history of this species showed that adults emerging November 25 came to their natural death during the period January 1 to 15, while those emerging June 10 succumbed between July 1 and 15. This shows that during the dry winter months approximately two months are required from the time of emergence to the completion of the life period, while during the humid summer months approximately a month is required.

Molting process.—Before molting the mite securely attaches itself to the leaf. In emerging from the quiescent stage the old skin splits transversely along the cephalothoracic-abdominal suture. Following the splitting of the skin the anterior end of the mite is slowly drawn from the old skin. With the use of its fore legs the mite forces its way out from the shell.

Parthenogenesis.—Some immature individuals were isolated on a number of plants. From these individuals virgin females were obtained. These females produced eggs and in each instance the resultant individuals were males.

Migration.—There does not seem to be an alternate host of this species. Individual red spiders may be found on the avocado at any time during the year in varying numbers, and never leave the tree for want of a new or alternate host plant on which to feed. In a grove the red spiders are spread from tree to tree by the wind, birds, etc.

Generations of the species.—The generations of the avocado red spider fluctuate as to number and overlap considerably. In years of little rain during the fall the red spiders come in evidence more quickly than when rains occur earlier. Intermittent rains frequently

occurring during the red spider season also interfere with the regularity of the generations. Activity of the red spider usually commences during the latter part of August and ceases the first part of April, giving an active season of about 240 days. The average duration of the life cycle is 14.2 days, which would give 17 generations. This would be true where no interruptions due to climatic conditions occurred, and when no other factors interfered with the normal activities of the mites in the field.

Shedding of the foliage.—During the winter months the foliage may be termed “dormant,” no new growth being present on the trees. Usually during the latter part of March and April the avocado commences to bloom and the older leaves, which have served their purpose to the trees, commence to fall. With the shed leaves many mites are lost and do not regain positions on the trees. During the latter part

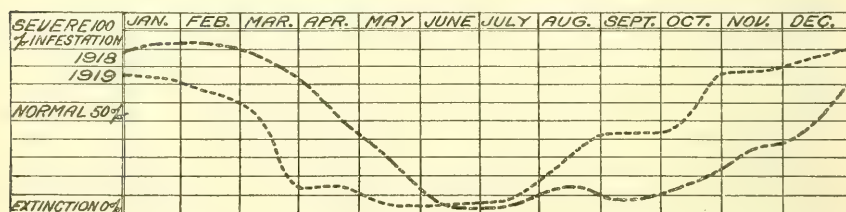


FIG. 4.—Curves showing 2-year composite seasonal status of the avocado red spider in southern Florida. The decimations arising through the amount of precipitation are the most important controlling factor in the activities of the species.

of April very little old foliage is present and a remarkable reduction of red spiders is apparent. A few old leaves, however, always remain on the trees until the newer growth has hardened and thus enable the red spiders to remain continuously on the trees and to infest the newer growth when it hardens.

Climatic control.—Climatic conditions existing in Florida influence the development and activity of the red spider to a marked degree. This particular species, as has already been stated, confines its depredations to the upper surface of the foliage. The species so working is exposed to the weather conditions. Hence during the period of the life cycle or seasonal cycle there is a series of fluctuations in numbers. In April, as the rainy season approaches, the red spider barely maintains existence. (Fig. 4.) During the months of June, July, and August no pronounced gain is made, but toward the latter part of October the avocado ceases to produce new growth, the red spiders commence to make their appearance in greater numbers, and increase during November and December. They usually reach the maximum number during January and February, and decrease again toward March. Precipitation is the one climatic factor important in reducing the red spiders during the spring and summer.

(Fig. 5.) During the summer in Florida drenching and frequent rains usually prevent the red spiders from establishing themselves on the trees. During late fall and winter and early spring it rains seldom, and the interference with the activities of the red spider is slight.

PREDATORY ENEMIES.

A number of predatory enemies of the avocado red spider aid at various times in keeping down the species on the avocado to a small degree.

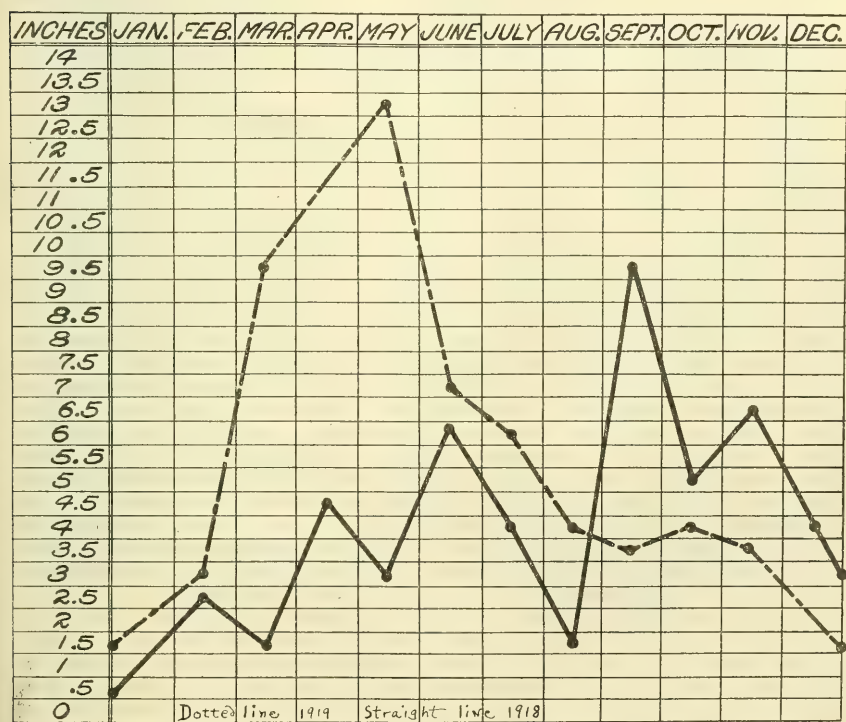


FIG. 5.—Precipitation chart for the years 1918 and 1919 in southern Florida.

Scolothrips sexmaculatus Pergande is one of the predatory thrips and is not abundant during the height of the red-spider season. Nevertheless it is present doing its share of destruction. It is a light-colored thrips possessing six dark spots on its body. It feeds on the red spiders in both the larva and adult stages.

Chrysopa lateralis Guer. is one of the so-called lace-wing flies and is predatory in the larva stage on the red spider. The larvæ, while feeding and wandering about the foliage in search of their prey, carry with them a protection consisting of foreign material, such as cast red spider skins, etc. The larvæ have a voracious appetite and

possess powerful jaws with which they attack their prey. This species is quite beneficial.

Scymnus utilis Horn.—The most important enemy of the red spider found up to this time is a very small black ladybird beetle

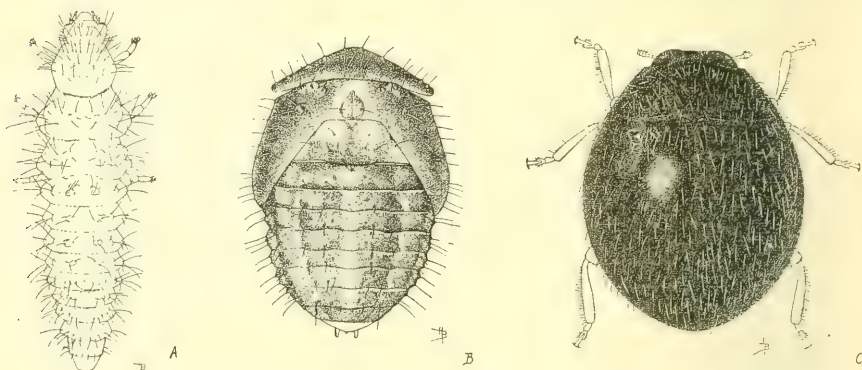


FIG. 6.—*Scymnus utilis*: a, Larva; b, pupa; c, adult. Greatly enlarged.

(fig. 6, c) about $\frac{1}{16}$ -inch long. With the beetles may be found their dark brown larvæ (fig. 6, a), also feeding on all stages of the red spider.

Scymnus kinzeli Casey is another ladybird beetle found feeding in both the larva and adult stages on the red spider. It is larger than

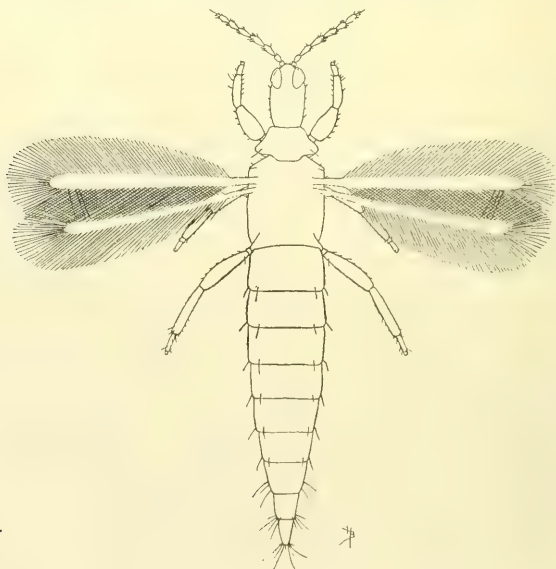


FIG. 7.—*Leptothrips mali*: Adult thrips. Greatly enlarged.

the former, the abdomen is black, and the head reddish. It is not a very abundant species and is not as beneficial as the former beetle.

Leptothrips mali Hinds is a large black thrips (fig. 7) predatory in both the larva and adult stages, and when present is very active

on the foliage in search of red spiders. It is not very abundant at any time.

SPRAYING EXPERIMENTS.

A number of insecticides have been tried out to ascertain their relative merits against the avocado red spider. The experiments were all conducted cooperatively with growers and in groves where the mite was abundant.



FIG. 8.—Power duster in operation using sulphur dust against the red spider in an avocado grove.

SULPHUR DUST.

An impalpable sulphur dust was tested on both the West Indian and Guatemalan races of avocados. In applying the material a power duster (fig. 8) was used. The sulphur proved to be very effective against the species, killing 99 per cent of the spiders, and remaining effective on the foliage over as long a period as did any of the liquid sprays tested. Experiments with this material showed that it was not necessary to apply the sulphur dust when the foliage was wet with dew. Where an avocado grower has a large acreage and the red spider is the only serious enemy to contend with, the dusting method is very practical and by far the quicker method. At the present time, however, the avocado grower has other insect pests with

which he has to contend, making it necessary to use liquid insecticides in combination with a sulphur spray in some form for their control. Up to this time the writer has not found it practical to use a combination of sulphur dust and 40 per cent nicotine sulphate against the insects of the avocado.

LIME-SULPHUR CONCENTRATE.

In using lime-sulphur concentrate spray on the avocado a number of strengths were tried, e. g., 1 gallon of concentrate to 40 gallons of water, 1 to 60, and 1 to 75. In spraying with lime-sulphur solution it was found through actual count that nothing is to be gained in applying too strong a solution of lime-sulphur to red spiders on the avocado. A strength of 1 gallon of the concentrate to 60 gallons of water proved to be the most efficient, generally killing 99 per cent of the spiders and producing sufficient body as a spray on the foliage to remain effective during the dry season against later hatching young. Under certain conditions applications of 1 to 40 and 1 to 60 were too strong, and considerable damage resulted to the foliage from burning, especially on the south side of the trees. When the temperature is above normal during the winter season, or when the trees do not attain a thoroughly dormant condition, a strength of 1 gallon of the concentrate to 75 gallons of water was found satisfactory. It was also ascertained that it is not necessary to incur the extra expense of adding a spreader of lime-sulphur spray, such as flour paste, glue, or fish-oil soap, because good results were obtained without it.

COMMERCIAL SODIUM SULPHID.

Commercial sodium sulphid was used at a strength of 2 pounds to 50 gallons of water. It was ascertained that this spray killed approximately 95 per cent of the red spiders present. Because of its chemical composition, however, the spray did not dry thoroughly on the foliage. The hygroscopic condition so formed permitted the spray covering the eggs and foliage to be readily washed off by succeeding rains, and nothing remained to destroy the hatching young.

NICOTINE SULPHATE CONTAINING 40 PER CENT NICOTINE.

At times the red spiders make their appearance during the fall before the fruit is picked. At this time it is not advisable to use any of the sulphur sprays, as they adhere to and discolor the fruit. By using 40 per cent nicotine sulphate at the rate of 1 part to 900 parts of water, with the addition of 2 or 3 pounds of fish-oil soap to each 100 gallons of the diluted spray as a spreader, satisfactory results were secured. The spray, however, proved to be effective only

temporarily, as none remained on the foliage to destroy the young on hatching.

SPRAY ROD VERSUS SPRAY GUN.

In making a comparison of the spray rod (fig. 9) and the spray gun (figs. 10 and 11) it was found that the latter gave better satisfaction against the red spider. Where an orchardist is short of help considerable benefit can be derived by using the spray gun, as the spray operator can cover the ground much faster than when using

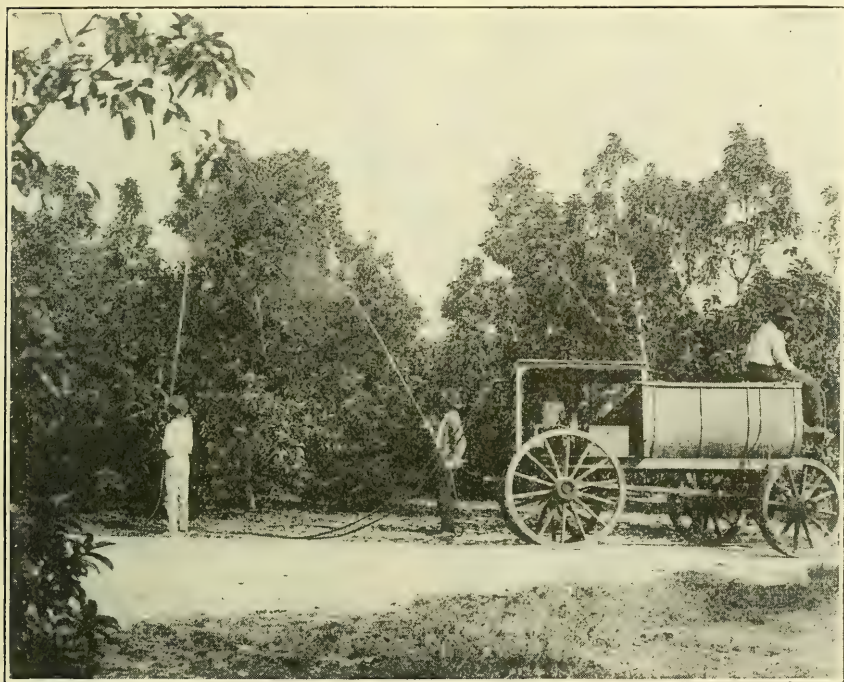


FIG. 9.—Spraying in an avocado grove with spray rods.

the spray rod. As the red spider works on the top of the foliage the operator can stand off a short distance from the tree, and with the use of the spray gun can spray from the bottom to the top of the tree by turning the handle of the gun which changes the spray from the fan or fog spray (fig. 10) to a long-distance spray (fig. 11).

The writer has found that growers in using the spray gun often neglect to change the disk in the nozzle frequently enough and wonder why they can not maintain sufficient pressure while spraying. The operator should watch the opening of the disk in the nozzle of the gun, and should replace it when it is worn.

CULTURAL METHODS IN THE GROVE.

Clean culture does not play an important part in the control, as this species does not infest weeds or plants in or about avocado groves. Orchards mulched in various ways in southern Florida were found to be less infested with the red spider as a rule than those where clean culture was practiced. The avocado seems to thrive better where mulching is practiced and the moisture is conserved. Red spiders generally like dry conditions such as are afforded in



FIG. 10.—Spraying in an avocado grove with spray gun, using the fan or big fog spray.

groves where clean culture is followed. This is especially evidenced in seasons of drought during the year.

One factor which influences greatly the abundance and appearance of the red spider in a grove is the vitality of the trees. Nothing is to be gained by allowing trees to suffer from want of proper attention in the way of mulching, plant foods, and culture. Where growers are in doubt about the proper procedure to use in caring for their avocado trees, they should get in touch with either the Plant Introduction Garden maintained by the United States Bureau of Plant Industry at Miami, Fla., or their particular county agent.

RECOMMENDATIONS.

The presence of the avocado red spider on the trees in considerable numbers while the foliage is still green should be a sufficient indication of impending injury to cause the grower to begin immediate application of control measures. The grower should not wait until the foliage attacked becomes noticeably brown prematurely and begins to drop.

During the winter after the fruit has been picked use the liquid lime-sulphur 1 to 60. When the temperature is above the normal and the trees do not attain a thoroughly dormant condition the liquid lime-sulphur should be reduced to 1 to 75.



FIG. 11.—Spraying in an avocado grove with spray gun, using the long distance spray.

If the red spiders are present while the fruit is still unpicked in the fall, 40 per cent nicotine sulphate 1 to 900, with the addition of 2 or 3 pounds of fish-oil soap to each 100 gallons of the diluted spray, will give temporary relief and will not discolor the fruit.

Thorough application is a most essential point in combating the red spider.—If haphazard work is performed and much of the foliage left unsprayed, such infested foliage serves as a source of reinfestation to the tree, and the mites will be more in evidence after application than when thorough work has been done.

•

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1036



Contribution from the Forest Service
WILLIAM B. GREELEY, Forester

Washington, D. C.

October 20, 1922

COAL-TAR AND WATER-GAS TAR CREOSOTES: THEIR PROPERTIES AND METHODS OF TESTING.

By ERNEST BATEMAN, *Chemist in Forest Products.*

CONTENTS.

	Page.	PART III—Continued.	Page.
PART I. Tars and the production of creosotes from tars.....	3	Chapter II. Physical properties of coal-tar creosotes.....	50
Chapter I. Introduction and definitions.....	3	Chapter III. Toxic properties of coal-tar creosotes.....	66
Chapter II. Composition of tars and methods of manufacture.....	7	Chapter IV. Composition and properties of water-gas tar creosotes.....	73
Chapter III. Production of creosote from tars.....	19	Chapter V. Comparison of the properties of commercial coal-tar creosotes and commercial water-gas tar creosotes.....	77
PART II. Experimental comparison of authentic specimens of creosote.....	23	Chapter VI. Tar-creosote solutions.....	79
Chapter I. Collecting and testing the specimens of creosote.....	23	Chapter VII. A theory of the mechanism of the protection of wood by oil solutions.....	84
Chapter II. Determining certain conditions for the tests.....	35	PART IV. Methods of testing creosotes and official specifications for creosote.....	87
Chapter III. Results of the tests.....	38	Chapter I. Practical methods of testing creosotes.....	87
Chapter IV. Comparison of the properties of authentic coal-tar creosotes with those of authentic water-gas tar creosotes.....	44	Chapter II. Specifications now in force by various associations.....	103
PART III. Properties of creosotes.....	47	Appendix.....	106
Chapter I. Composition and chemical properties of coal-tar creosote.....	47	Bibliography.....	112

FOREWORD.

Creosote as a preservative is widely used in this and certain other countries, and a considerable number of articles have been published from time to time on its chemical, physical, and toxic properties. Most of these articles appeared in various technical periodicals, in the proceedings of a number of societies, or in the form of Government bulletins. It is believed that the presentation of the substance of these articles in compact form will be serviceable to those interested in the use of creosote for preserving wood. In addition to giving such a summary, this bulletin also makes available the hitherto unpublished results of certain minor investigations and also of an extended research conducted at the Forest Products Laboratory at Madison, Wis., primarily for the purpose of obtaining a broader knowledge of

the variations of creosote with different processes of manufacture. The bulletin also presents descriptions of the different methods of testing creosotes which have been used or suggested, and particularly those now adopted as standard by the various associations interested in wood preservation, and gives a discussion of the value of the methods of testing.

The bulletin has been divided into four parts. Part I includes the introduction, a description of tars, and an account of the manufacture of creosote. Part II is a presentation for the first time of the results of researches by the author and his coworkers in the Forest Products Laboratory. Part III gives a summary of the chemical, physical, and toxic properties of creosotes as a whole. Part IV is concerned entirely with methods of testing and specifications.

The author wishes gratefully to acknowledge the services of Messrs. L. E. Cover and J. P. Mehlig, formerly assistant chemists in forest products. Much of the routine work described in Part II was done by one or the other of these gentlemen.

PART I. TARS AND THE PRODUCTION OF CREOSOTES FROM TARS.

CHAPTER I. INTRODUCTION AND DEFINITIONS.

The preservative treatment of wood is widely recognized to be of great importance, not only in its bearing upon the conservation of our forest resources, but also because it is a large factor in reducing the annual expense for upkeep in those industries that use large amounts of timber under conditions in which it is particularly liable to destruction by the lower forms of organized life. The importance of the

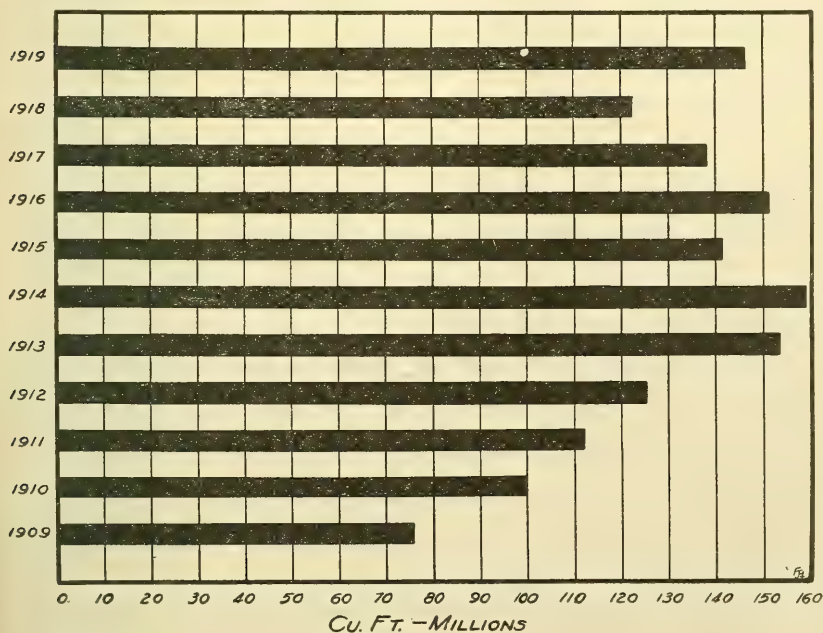


FIG. 1.—Total material treated (1) by wood preservatives.

wood-preserving industry is indicated by the diagram (fig. 1), which shows the total amount of timber annually treated with preservatives in this country for the years 1909 to 1919, inclusive.

DEFINITIONS.

The term "creosote," or "creosote oil," has such a wide variation in meaning that all statistics include, in all probability, not only the product obtained from the distillation of coal tar, but also mixtures of the distillates with crude, refined, or filtered tar, mixtures of water-gas tar distillates, and mixtures of coal-tar distillates and water-gas tar. It is, therefore, advisable to define the terms that will be used in this bulletin.

If the meaning of coal-tar creosote is to be understood, a definition of the mother liquors, or tars, from which the creosote is obtained is necessary.

Tar is defined as a nonaqueous, viscous liquid of very complex composition produced by the destructive distillation or partial combustion of organic matter or of minerals containing organic matter.

Coal tar is the tarry liquid obtained by the destructive distillation or partial combustion of bituminous or semibituminous coals.

High-temperature tar is produced from bituminous or semibituminous coal at temperatures so high that it contains principally aromatic hydrocarbons, such as benzene, naphthalene, anthracene, and similar substances. It also contains well-defined amounts of phenoloids and tar bases. The conditions for the manufacture of this high-temperature tar prevail in the usual gas-house retort and by-product coke oven. High-temperature tars are divided into two classes—retort tar and coke-oven tar.

(1) *Gas-house or retort tar* is a high-temperature coal tar produced in a gas-house retort. Three types are recognized and derive their names from the type of retort in which the coal is coked. (a) *Horizontal-retort tar* is a high-temperature coal tar produced in a horizontal gas-house retort; (b) *inclined-retort tar* is a high-temperature coal tar produced in an inclined retort; (c) *vertical-retort tar* is a high-temperature coal tar produced in a vertical retort.

(2) *Coke-oven or by-product tar* is a high-temperature coal tar produced in a coke oven from bituminous or semibituminous coal. At least three classes are made in this country and derive their names from the type of oven in which they are produced. (a) *Otto tar* is a high-temperature coal tar produced in the Otto, the United Otto, or the Otto-Hoffman coke oven; (b) *Semet-Solvay tar* is a high-temperature coal tar produced in a Semet-Solvay oven; (c) *Koppers tar* is a high-temperature coal tar produced in a Koppers coke oven.

Low-temperature coal tar is produced from bituminous, semibituminous, or cannel coal at such low temperatures that it contains hydrocarbons, principally of the paraffin or olefin series. It also usually contains large amounts of phenoloids and appreciable amounts of tar bases. Two general divisions are made—tars produced by destructive distillation and producer gas tars.

(1) Tars produced by destructive distillation include: (a) *Cannel coal tars* produced from cannel coal at relatively low temperatures. Cannel coal is in reality a highly bituminous shale, and if this tar is included under coal tars, then tars from other bituminous shales should also be included. Shale tar is produced from the bituminous shale found in southern Scotland. (b) *Lignite tar* is the tar produced by the distillation of lignite or brown coal. Lunge is the authority for the statement that this tar is produced in Europe for the manu-

facture of petroleum products in competition with the natural American oils. It also contains phenoloids and tar bases.

(2) *Producer tars* are those tars which are produced from bituminous or semibituminous coals in the manufacture of producer gas. They result from destructive distillation combined with a partial combustion of the coal. (a) Blast furnaces using coal are in effect practically gas producers. A small amount of tar is produced in them, but it is similar in composition to that made in gas producers. This tar is known as *blast-furnace tar*. (b) *Mond-producer tar* is obtained from a Mond producer using bituminous or semibituminous coal. Other bituminous-coal producers also yield tars. These are, in general, called by the name of the producer, as the Sutherland producer tar.

Oil tars are the tarry fluids resulting from the destructive decomposition or cracking of petroleum oils. Like coal tars, these fluids are exceedingly complex mixtures. The character of their hydrocarbons depends greatly upon the temperature at which the tars were formed.

Like the high-temperature coal tars, the *high-temperature oil tars* are very complex mixtures of compounds. The hydrocarbons are chiefly of the aromatic series. Benzene, toluene, naphthalene, phenanthrene, and methyl anthracene have been found in them; but so far as is known no true anthracene has been identified in the American oil tars. They are further characterized by the almost entire absence of tar acids and tar bases, and this seems to constitute the chief difference between this type of tars and high-temperature coal tar.

Water-gas tar is the tar produced from petroleum oil in the carburated water-gas machine. This tar is practically the sole representative of high-temperature oil tars. Very small amounts of high-temperature oil tar are produced by the destructive distillation or cracking of petroleum oils in the gas retorts. A sample of such tar examined several years ago by the author could not be distinguished from water-gas tar and could be distinguished from high-temperature coal tar only by its lack of phenoloids and tar bases.

Low-temperature oil tars are produced in the manufacture of pintsch gas and are obtained as a residuum in the distillation of petroleum. They are characterized by an almost total absence of aromatic hydrocarbons and by a lack of phenoloids and tar bases. No further discussion of this class of tars is necessary for the purposes of this bulletin.

The term *creosote* is properly applied to the phenoloid bodies obtained from wood tar after they have been freed from the hydrocarbons, and the term is still used in this connection by druggists. A secondary meaning for creosote applies to a similar product

obtained from coal tar, and, in this respect it means the mixture of phenoloids known to the wood preserver as tar acids.

Creosote oil is the term correctly applied to that portion of wood tar or coal tar from which creosote may be obtained by extraction with caustic soda and a subsequent neutralization of the aqueous liquors with mineral acids.

Common usage in the wood-preserving industry has led to the disuse of the word "oil" and to the application of the term "creosote" to the mother liquor, or crude oil, from which true creosote may be obtained. Because of the similarity in other respects between the oil obtained from coal tar—that is, the true creosote oil—and that obtained from water-gas tar, the term "creosote oil" has been applied to oils containing no phenoloids whatsoever. In this publication, the term "creosote" is applied only to a pure product obtained by the distillation of tars, and will be restricted to the oils obtained from high-temperature coal and oil tars and to wood tars. They will be further defined by the use of some qualifying word or phrase such as coal-tar creosote or water-gas tar creosote. All the distilled oils (except patented or proprietary articles) will be called oils or distillates, and suitably designated to show their derivation. Mixtures of distilled oils with their mother liquor or with the mother liquor from other distilled oils will be termed tar solutions. More specifically, these terms are defined as follows:

Coal-tar creosote is defined as any and all distillate oils boiling between 200° and 400° C., which are obtained from high-temperature coal tars by distillation only. The addition or admixture of tars from any mixture or source, either refined, filtered, or crude, is not permitted under this definition.

Water-gas-tar creosote is defined as any and all distillate oils boiling between 200° and 400° C., which are obtained from water-gas tar or other high-temperature oil tars by distillation only. Admixture of other materials than those stated above changes the nomenclature.

Wood-tar creosote is a distillate oil obtained from wood tar. It has a specific gravity greater than 1 and distills principally above 170° C. at atmospheric pressure.

Shale oil is the oil obtained from the distillation of shale tar.

Mond oil is the oil from the distillation of Mond-producer tar.

Petroleum oil is used in the ordinary meaning, but also includes the oil from low-temperature oil tars.

Retort oil is the distillate above 200° C., obtained from low-temperature coal tars produced in the gas retort. It is similar in composition to Mond oil.

CHAPTER II. COMPOSITION OF TARS AND METHODS OF MANUFACTURE.

The character of the tars from which creosotes are made determines in the main the character of the creosote. The methods used in producing the oil may have a slight effect upon the character of the creosote if the tar contains only small amounts of the "paraffin" bodies, but those methods would not change a low-temperature tar to a high-temperature tar. These two classes of tar are determined by the methods used in producing the tar itself. A short description of the method of manufacturing tar and of the general character of the tar as to both its chemical and physical properties is, therefore, very essential as a basis for the discussion of creosotes. Tars of all descriptions are usually by-products of the manufacture of other materials and, consequently, are subject to wide variation, for the reason that, as a rule, no attempt is made to control their composition other than for the purpose of facilitating their removal.

COAL TAR.

Coal tar is obtained by the destructive distillation of bituminous or semibituminous coal. The main products of this reaction are coke and gas; the chief by-products, ammonia and tar liquor. Coal is generally distilled either for the production of illuminating gas or for the production of metallurgical coke. Whichever product is desired, the other is usually considered of secondary importance, and all the conditions are regulated to give a maximum yield of the highest quality of the main product. Whether gas or coke is to be the main product, there are differences in the character of the coal used, differences in the amount of coal used in each charge, differences in the time taken to carbonize, and differences in the temperatures used. A few coke plants are so situated that they have a demand for gas as well as coke, and in them both materials are principal products. Under such conditions slightly different methods of operation may be followed. However, the fundamental conditions governing the distillation of coal will always apply.

COMPOSITION AND DESTRUCTIVE DISTILLATION OF COAL.

Considerable work has been done upon the composition of various coals, and perhaps the most simple explanation of the different

products obtained from coal is given by Lewes (2),¹ who considers that all coals are composed of—

- | | |
|---------------------|------------------|
| A. Carbon residuum. | C. Resin bodies. |
| B. Humous bodies. | D. Hydrocarbons. |

The proportion in which these four components are mixed can be made to account for all the various coals known. He considers, for instance, Nottingham coal as made up of A B C D; coking coals in general as made up of 3A B C 3D; anthracite as being made up of 5A 2C. Three of these four constituents, namely, the humous bodies, the resin bodies, and the hydrocarbons, when subjected to heat, are partially or completely decomposed. The temperature at which this decomposition begins is probably between 300° and 400° C. The problem of tar formation is, however, complicated by the fact that most coal distillation is carried out in a retort or oven heated to approximately 1,000° C. This high temperature makes the composition of the tar very complicated, as it affords an opportunity for at least three different reactions to take place in the same coking chamber at approximately the same time. The primary reaction is a decomposition of the coal into those products which are formed by low-temperature distillations; the secondary reaction is a decomposition into simple products of some of the more complicated products of the primary reaction, and the tertiary reaction consists of a recombination of the simple products into aromatic hydrocarbons which are stable at high temperatures. These reactions are going on at the same time and may be complete or only partially so, depending upon several conditions. The various constituents of coal, according to Lewes, yield the primary-reaction products shown in Table 1.

TABLE 1.—*Primary-reaction products of coal.*

	Gaseous products.	Liquid products.	Solid products.
Humous bodies.....	{Carbon monoxide..... Carbon dioxide..... Methane.....	{Water..... Thin tar.....	}Free carbon.
Resin bodies.....	{Carbon monoxide..... Carbon dioxide..... Ethylene and other unsaturated hydrocarbons.....	{Water..... Thin tar.....	
Hydrocarbons.....	Methane, ethane, and other paraffins.....	Heavy tar.....	{Free carbon. Pitch.

The primary reaction may give the hydrocarbons shown in Table 2, all of which have been found in the distillation products of coal decomposed at low temperatures.

¹ All italic figures inclosed within parantheses refer to the bibliography, in which numbers are assigned to the different articles of literature.

TABLE 2.—*Hydrocarbons found in the primary-reaction products of the distillation of coal.*

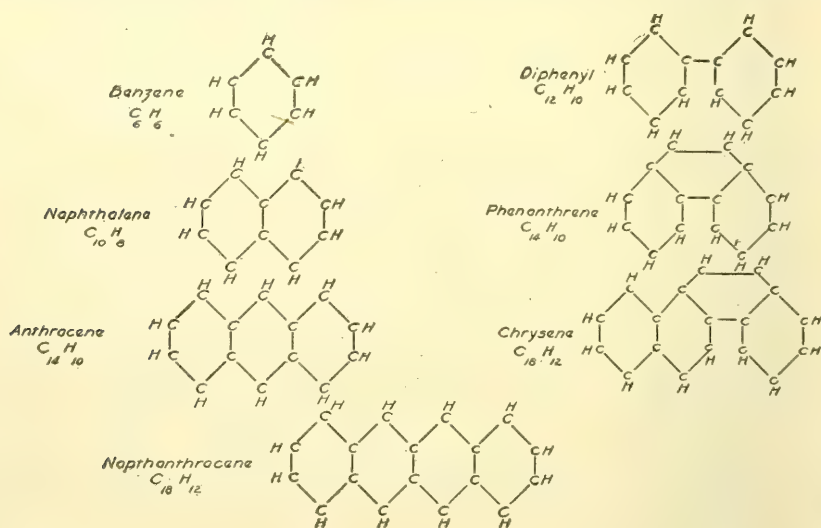
Saturated hydrocarbons.		Unsaturated hydrocarbons.		Naphthenes.
Methane	CH ₄	Ethylene	C ₂ H ₄	Hexahydrobenzene C ₆ H ₁₂ .
Ethane	C ₂ H ₆	Propylene	C ₃ H ₆	
Propane	C ₃ H ₈	Butylene	C ₄ H ₈	
Butane	C ₄ H ₁₀	Amylene	C ₅ H ₁₀	
Pentane	C ₅ H ₁₂	Hexylene	C ₆ H ₁₂	
Hexane	C ₆ H ₁₄	Heptylene	C ₇ H ₁₄	
Heptane	C ₇ H ₁₆			
Octane	C ₈ H ₁₈			
Nonane	C ₉ H ₂₀			
Decane	C ₁₀ H ₂₂			
Possibly	paraffins.....			

All these hydrocarbons, both gaseous and liquid, are similar to what we obtain from crude petroleum. In addition to the above, the oxygen in the coal is probably in a large measure converted into oxides of carbon and phenols, as we find these materials in great abundance in low-temperature tars. All of the products of the primary reaction, with the exception of the gaseous carbon monoxide, carbon dioxide, methane, and ethane, will undergo decomposition at somewhat higher temperatures into more simple hydrocarbons with a production of the permanent gases, methane, ethane, ethylene, acetylene, and hydrogen. This is the secondary reaction. The products of the secondary reaction probably contain compounds having three carbon atoms or less, with the exception of possibly small amounts of benzene and xylene, which result from the decomposition of the naphthenes. We should expect that this phase of the reaction would produce chiefly hydrogen; the saturated hydrocarbons—methane, ethane, and possibly propane; and the unsaturated hydrocarbons—ethylene, propylene, acetylene, and amylenes. All of these, as well as different members of the acetylene series, have been identified as products of the distillation of coal. If the gas maker could so arrange his distillation that only the first and second reactions would take place, it would probably be a very satisfactory arrangement for him. In order, however, to heat the coal hot enough all the way through to induce a secondary reaction as nearly complete as possible, it is necessary to superheat the retorts or ovens, and, as a result, a third reaction may and does take place.

The tertiary reaction consists in building up more complex but more stable compounds from the more simple ones. This reaction is often accompanied by the elimination of hydrogen. The hydrocarbons formed are those classed by the chemist as aromatic hydrocarbons, and they differ from the paraffin hydrocarbons in containing less hydrogen per carbon atom, in the arrangement of the carbon atoms themselves, in their chemical reactions, and in their resistance to heat. The aromatic hydrocarbons may be subdivided into a

large number of different groups, of which those shown in the diagram may be considered the simplest members of a few typical groups.

All of these compounds except naphthanthracene have been positively identified in coal tar, and very probably that one is present also. Many more combinations and structures are, of course, possible, for which the reader is referred to Beilstein's *Organische Chemie*. The general course of these reactions is probably somewhat as follows: Three acetylenes, C_2H_2 , combine to form benzene, C_6H_6 ; 2 benzenes unite to form diphenyl with the elimination of hydrogen; 1 benzene and 2 acetylenes combine to form naphthalene; 2 benzenes and 1 acetylene combine to form phenanthrene or anthracene; 1 benzene, 1 naphthalene, and 1 acetylene combine to form either chrysene or naphthanthracene. These reactions may take place in this manner



or through various intermediate stages. Part of these reactions, at least, have been carried out on a laboratory scale; others have followed the same general course, but have taken two or more stages in which to accomplish the final result.

From the above it is evident that, on the one hand, coal tars may be obtained containing large amounts of paraffins if the secondary and tertiary reactions are kept at a minimum; or, on the other hand, tars containing a predominance of aromatic hydrocarbons if the secondary and tertiary reactions are complete or nearly so. All stages of coal tars are known, from paraffin tars produced at low temperatures to aromatic tars produced at high temperatures. The tars generally used for the production of coal-tar creosote are those produced at high temperatures, but they may, under certain conditions, contain low-temperature tars. These reactions are governed by the

temperature of the gases, and this in turn is governed by the temperature of the retort and the time of contact of the gases with the heated walls. The time of contact of the gases with the walls is governed to some extent by the type of retort or oven used and the manner in which it is filled.

APPARATUS USED IN THE PRODUCTION OF COAL TAR.

As indicated before, high-temperature coal tar results in connection with the production both of illuminating gas and of coke. The apparatus and methods used, although they involve the same general reactions, differ in the following respects: First, the coals are different. In general, gas coal contains from 30 to 40 per cent of volatile matter, while the coal used for the production of coke contains from 15 to 25 per cent of volatile matter. Second, the sizes of the coking chambers are different. The capacity of the gas retort is measured by the hundredweight of coal per charge; the capacity of the coke oven is measured by the ton. The time of coking in gas-house practice may vary from 6 to 12 hours; in coke ovens it may vary from 24 to 60 hours.

There are three different types of gas benches used in this country, each type in general having several different subdivisions. The three types receive their names from the position of the retort itself. They are the horizontal retort, the inclined retort, and the vertical retort.

Horizontal-retort benches.—Horizontal retorts have a cross-section similar to the letter D laid on the flat side, and are about 18 inches wide and 15 inches high. They may be 6 to 18 feet long. The retort may be heated by direct coal fire, as in the older systems; or by producer gas, as in the more modern types. The coal may be charged by hand, sometimes by shovel, sometimes by a specially constructed trough or scoop; or by machinery, a retort known as the "through retort" having come largely into use. Figures 2 and 3 show views of a bench of machine-charged retorts. The hand-charged retort is usually filled about 6 inches in depth with coal, but it is possible to fill the machine-charged retort 12 inches deep. It has been shown by Lewes (2) that in the conditions first described the gas formed at the bottom of the retort rises through the charge and escapes from the retort chiefly through the space above the coal, and that it must of necessity come in very close contact with the heated walls of the retort. This almost assures a complete tertiary reaction. On the other hand, if the retort is filled, as it is possible for it to be with machine charging, the gas may escape largely through the center of the charge, which is cooler, and there may not be so complete a tertiary reaction. The tar would then not be composed entirely of aromatic hydrocarbons. Another factor that may enter into the

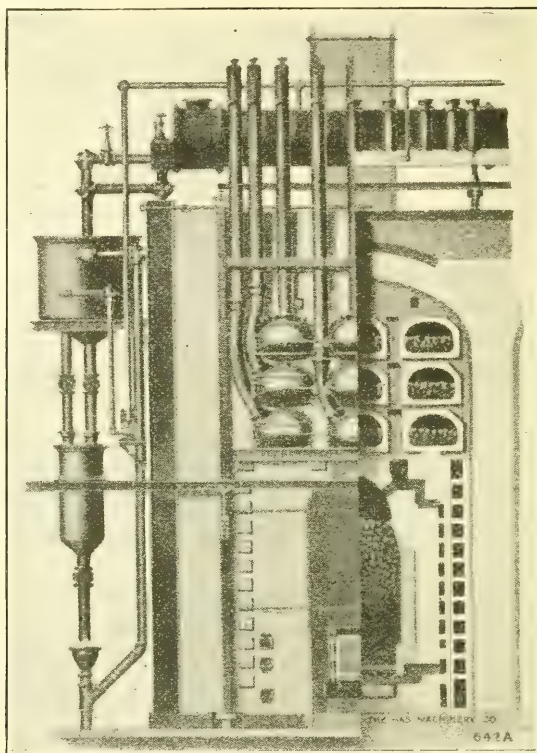


FIG. 2.—Cross-sectional view of bench of machine-charged horizontal retorts.

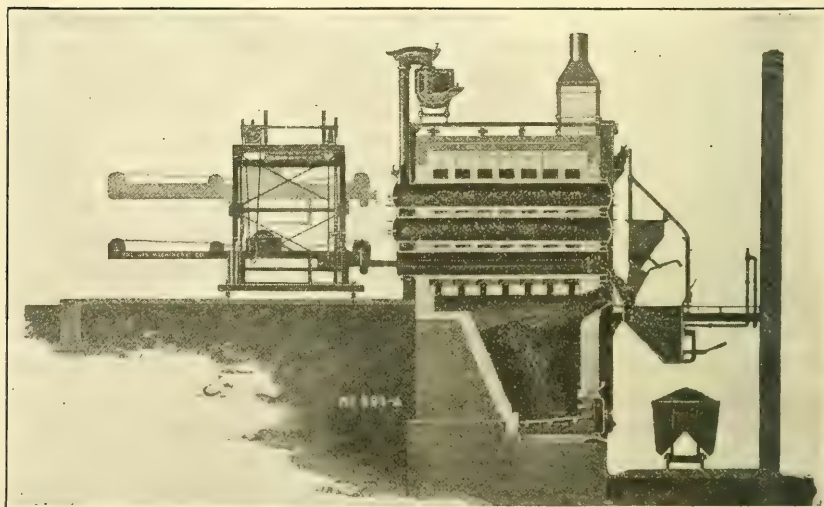


FIG. 3.—Longitudinal view of bench of machine-charged horizontal retorts.

composition of tar is the relation of the equipment at the gas plant to the demand for gas. The most efficient manner of operating any plant is not always the most expedient. During the war, when it was hard or impossible to obtain machinery, and at the same time the demand for the manufactured products was great, by shortening the time of coking and not attempting to remove all the gas, it was then found possible to increase the output of a given equipment to a considerable extent. Under such conditions the tar would be produced at a lower average temperature and hence the paraffin content would be higher.

Inclined-retort benches.—In the inclined-retort system the retorts are set at an angle which is as near as possible to the angle of recline of coal. This is in the neighborhood of 30 degrees. Coal is charged by gravity at the upper end of the retort, and under ideal conditions fills the retort to an even depth for its full length. This condition is not always realized in practice, and not infrequently a considerable amount of unburned coal is found near the lower door, while the upper part of the retort is nearly bare. This results in the tar containing high amounts of paraffin. At the present time the use of this system is not extending in this country.

Vertical-retort benches.—The fact that much space in textbooks is being devoted to the vertical retort would seem to indicate that in time this type of retort may replace the horizontal for gas-making purposes. The retorts are oval in cross-section and slightly larger at the bottom than at the top. The coal is charged and the coke extracted by gravity. For this reason the coal completely fills the cross-section of the retort. The escaping gases are, therefore, forced to travel chiefly through the cool core of uncarbonized coal. The resulting tars contain considerable amounts of paraffin bodies. In general, the specific gravity of tars from vertical retorts is less than that of tars from horizontal rerorts.

By-product coke ovens.—There are several types of by-product coke ovens in this country, but by far the greater proportion of them belongs to one or another of three systems. These systems differ from each other in several ways, as in methods of heating, in methods of regeneration of heat, and in methods of recovery of by-products, but the general principle underlying the manufacture of coke is the same as that used in retort practice.

The three principal systems are the Otto system, with its various modifications, the Semet-Solvay system, and the Koppers system. Figures 4, 5, 6, 7, and 8 show views of these three types of oven. By-product coke ovens are, in general, long, rectangular ovens which may vary in height from 3 to 9 feet and may be as long as 35 feet. The width of the oven, however, varies within narrow limits, being 17 to 19 inches. Inasmuch as coke ovens are generally erected in

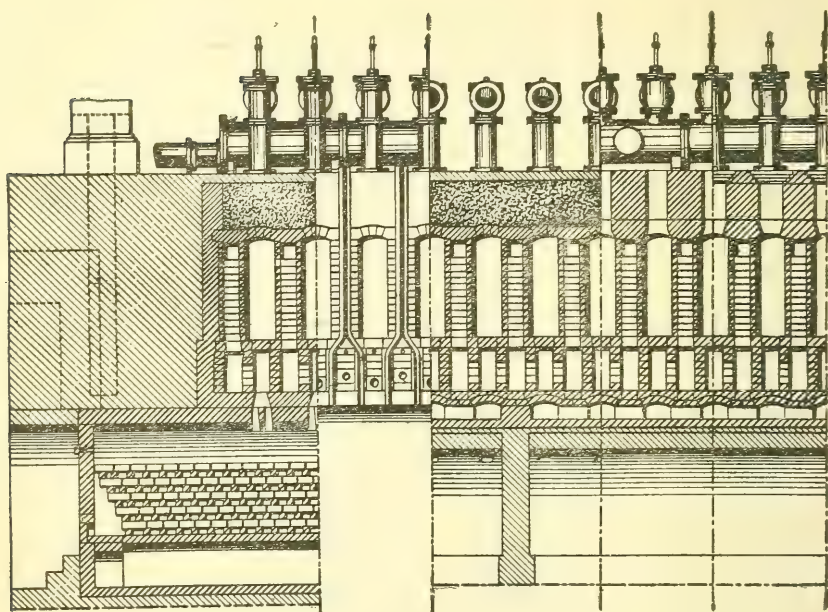


FIG. 4.—Longitudinal view of Otto-Hoffman (old style) coke ovens.

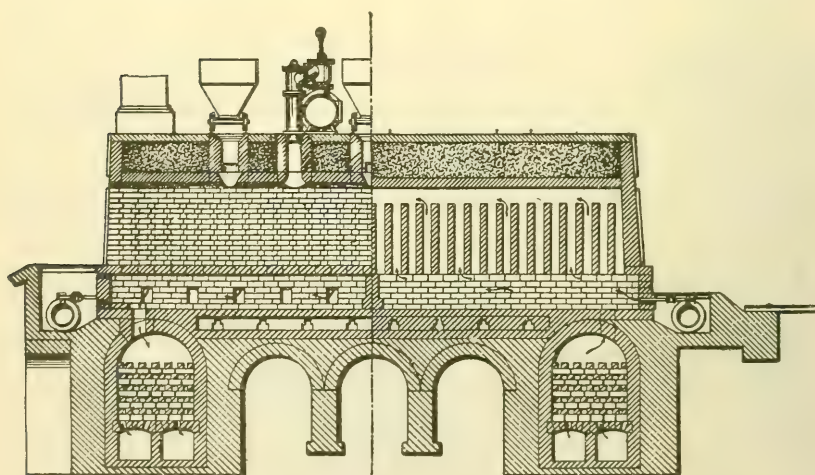


FIG. 5.—Cross-sectional view of Otto-Hoffman (old style) coke ovens.

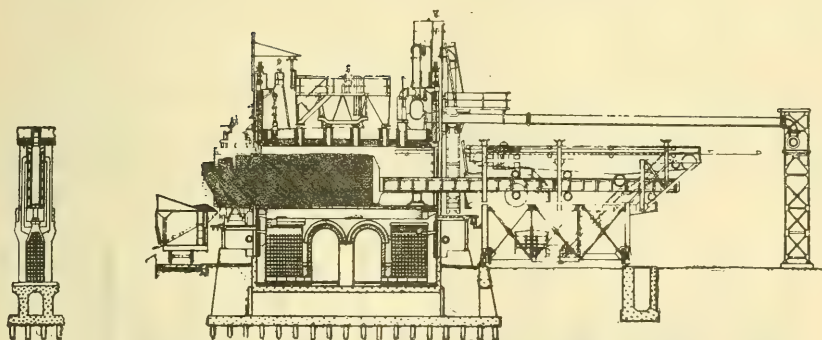


FIG. 6.—Cross-sectional and longitudinal views of Semet-Solvay coke oven.

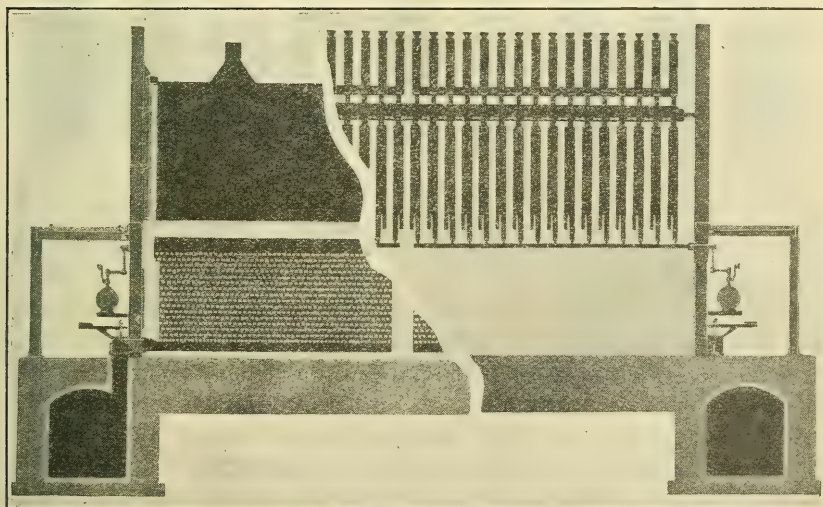


FIG. 7.—Longitudinal view of Koppers coke ovens.

batteries of 50 or more, side by side, there is but little chance to modify the method of heating. All of the ovens in this country, with the exception of the Semet-Solvay oven, heat the coking chamber by gas burned in vertical flues at the side of the chamber. The Semet-Solvay oven heats the coking chamber by gas burned in horizontal flues.

WATER-GAS TAR.

Water-gas tar is produced in the manufacture of carbureted water gas. This gas is produced in a machine known as a "water-gas set." It consists of three principal parts—a generator in which the true water gas is produced; a carburetor consisting principally of checker

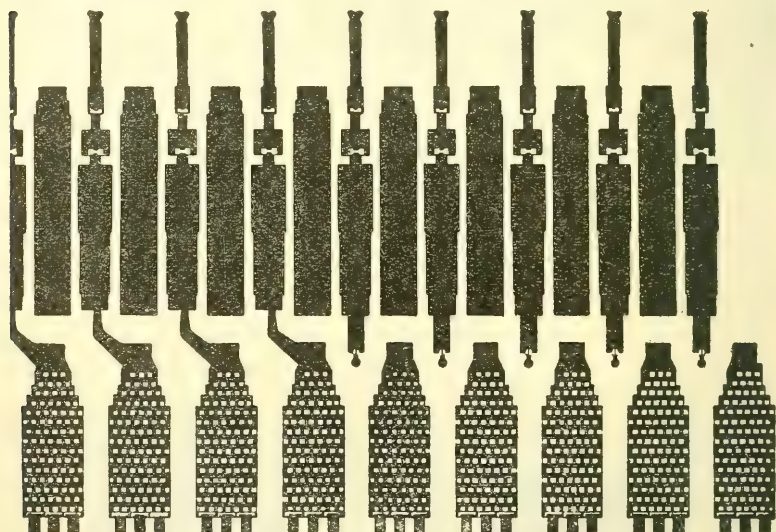


FIG. 8.—Cross-sectional view of Koppers coke ovens.

brick on which petroleum oil is sprayed in order to render the water gas of value for illuminating purposes; and a superheater, also of checker brick, in which the gases formed in the carburetor are fixed and made permanent. In operation the generator is filled to a suitable level with coke or anthracite coal. This is rendered incandescent by blowing through it air under pressure, the products of combustion passing through the carburetor, where they meet a secondary air supply and are completely burned in the carburetor and superheater. The gases passing from the superheater are allowed to escape in the stack and are lost, as they contain no material of heating value, and are used to obtain the proper temperature in the set. When the superheater and the rest of the water-gas set are of the proper temperature, the blowing is interrupted momentarily until the valves leading to the gas holder can be opened and the

escape valve closed. Steam is then blown through the coke bed, water gas being produced according to the equation $C + H_2O = CO + H_2$. As this gas enters the carburetor, gas oil obtained from petroleum is sprayed on the checker brick and cracked to permanent gases. This cracking and fixing of the gases is continued in the superheater. The gas, as it leaves the superheater, passes through condensers and scrubbers, where the tar is removed. The run with steam is continued until the temperature drops below a fixed point. This operation is then stopped, and the temperature is again raised by blowing. Table 3 shows a satisfactory set of operating conditions.

TABLE 3.—*Operating conditions in the water-gas set (4).*

Size of set.....	8 feet 6 inches.
Area of grate.....	33.2 square feet.
Fuel used.....	Oven coke.
Oil used.....	Lima gas oil.
Temperature at base of superheater.....	1,461° F.
Temperature at top of superheater.....	1,300° F.
Length of blow.....	3 minutes.
Length of gas make.....	4 minutes.

No tar is produced in the water-gas reaction itself, but is all obtained as a result of the cracking of petroleum oil. The same discussion which applied to the reactions taking place in coal-tar production apply equally well in this connection if we consider that the primary reaction as given under coal tar has already been performed by nature in the production of petroleum oil. Here again, as in producing coal gas, a gas manufacturer would prefer to have no Tertiary reaction; but, in the attempt to obtain a secondary reaction as complete as possible, some Tertiary products are formed. The presence of paraffin hydrocarbons in water-gas tar shows that, from the gas-maker's point of view, a waste has resulted from insufficient cracking and the presence of aromatic tars shows a decrease in illuminating value on account of a recombination of some of the illuminants. The gas maker desires to obtain as small an amount of highly aromatic tar as possible with complete cracking of the oil. The presence of the large amount of hydrogen in water gas probably suppresses to some extent the Tertiary reaction which would normally be obtained by cracking petroleum in the presence of its own decomposition vapors, as is done in the manufacture of Pintsch and Blau gas; but the effect of this suppression would be no greater than a similar effect which must take place in coal gas, for the latter contains more hydrogen than does water gas.

The yield of tar depends, therefore, upon the completeness of cracking of the oil, which, in turn, is dependent upon the temperature to which the oil vapors are brought and the character of the oil used. Table 4 gives a comparative yield of water-gas tar from different oils.

TABLE 4.—*Comparative yield of water-gas tar from different oils.*

Mixture contains—		Volume of tar produced.
Class of oil.	Base.	
Naphthas.....	Paraffin.....	<i>Per cent.</i> 2 to 4
Gas oils.....	do.....	6 to 10
Crude oils.....	do.....	8 to 12
Gas oils.....	Asphaltic.....	10 to 15
Crude oils.....	do.....	12 to 18

PRODUCTION OF TAR IN THE UNITED STATES.

The figures given in Table 5 show the number of gallons of coal tar produced in the United States since 1904:

TABLE 5.—*Production of coal tar in the United States.*

Year.	Retort tar.	By-product tar.
1904	41,726,970(5)	27,771,115(5)
1908	58,541,220(5)	42,720,009(5)
1912	40,489,855(6)	94,306,583(6)
1915	47,863,192(7)	138,414,601(7)
1917	53,318,413(7)	221,999,264(7)

No direct figures are available on the amount of tar produced by each type of retort or coke oven throughout this period. Some general idea may, however, be obtained from the following list of coke ovens in existence at the end of 1917: (8.)

Koppers.....	3,374	Rothberg.....	281
Semet-Solvay.....	1,831	Roberts.....	36
United Otto.....	2,032	Didier.....	150
Wilputte.....	78		
Gas machinery.....	60	Total.....	7,869
Klönne.....	27	Idle.....	571

The amount of water-gas tar produced and sold in this country as given by the United States Geological Survey is shown in Table 6:

TABLE 6.—*Production of water-gas tar in the United States.*¹

Year.	Produced and sold.
	<i>Gallons.</i>
1905	9,230,411(9)
1908	9,168,834(5)
1912	34,000,000(6)
1915	51,381,911(7)
1917	59,533,208(7)

¹ Fulweiler (56) gives the production of water-gas tar in 1918 as approximately 70,000,000 gallons; in 1919, 75,000,000 gallons; and in 1920, 80,000,000 gallons.

CHAPTER III. PRODUCTION OF CREOSOTE FROM TAR.

In commercial practice creosote is to a considerable extent a by-product of the manufacture of other materials. The details of the process, therefore, vary somewhat with the end product obtained. The process of manufacturing creosote consists, essentially, of the distillation of the tar and is in general the same, no matter what the end products may be.

The size and shape of the stills used for the purpose of commercial distillation vary somewhat according to the needs of the producer. In England and Germany, according to Lunge (10) and Warnes (11), the vertical still with a concave-upward bottom is preferred. Figure 9, taken from Lunge's *Coal Tar and Ammonia*, shows a cross-section of a 25-ton vertical still. Many stills of this general design are used in this country, but the horizontal still is more common. Figure 10 shows a battery of horizontal stills in use in this country.

The stills are filled to the proper level with crude or settled tar, preferably already heated by means of a preheater, and a slow fire is started under the still. In the early stages of the distillation extreme caution must be exercised, because most coal tar contains water, which can not readily be separated by standing. Too rapid heating will cause foaming or priming, with a loss of nearly the entire contents, unless the priming can be controlled.

In the United States it seems to be considered good practice to stir the contents of the still by using either air or steam, the former being preferred. This stirring aids in the prevention of foaming over during the early part of the distillation and results in a more rapid distillation when it is produced during the latter part of the process. A slight chemical reaction is also probably obtained. In Europe it is customary to inject steam into the still during the distillation of the anthracene oil. The number and graduation of fractions taken from coal tar depend largely on the markets for the various products. Warnes (11), an English writer, states that by far the greatest amount of tar distilled is divided into the following fractions: Crude naphtha, light oil, carbolic oil, creosote oil, anthracene or "green oil," and pitch. Lunge (10), in general, makes the same separation and gives the following temperatures as the cutting points of the various fractions:

Crude naphtha.....	Up to 105° or 110° C.
Light oils.....	From crude naphtha up to 165° or 210° C.
Carbolic oils.....	From light oil to 230° or 240° C.
Creosote oil.....	From carbolic oil to 270° C.
Anthracene oil.....	Above 270° C.

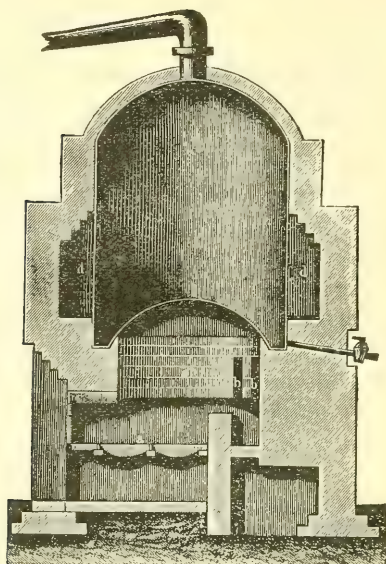


FIG. 9.—Cross-sectional view of European tar still. (Taken from Lunge's "Coal tar and Ammonia.")

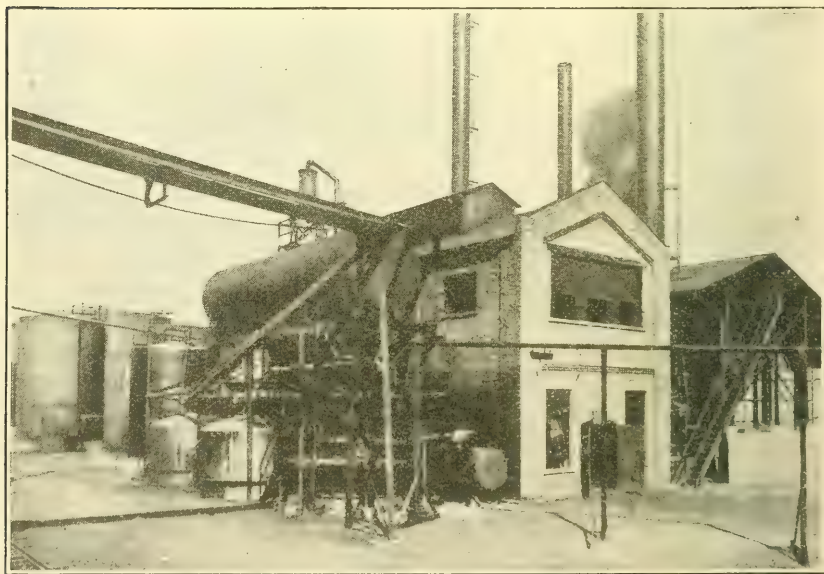


FIG. 10.—Battery of American tar stills and plant.

In this country there is little demand for either carbolic oil or anthracene oil. In general, therefore, these fractions are included in the creosote oil, and for the most part only three fractions are taken, namely, light oil, up to 200° or 210° C.; creosote oil, up to pitch; and pitch. The distillation is not carried so far as it is in Europe, but is run only to soft pitch. It is, therefore, expected that American oils will, in general, be somewhat lighter in specific gravity than the European oils, because the carbolic oils are usually included, and the distillation is not carried to so high a temperature.

It sometimes happens, however, when the demand for pitch is not very great, or when a special oil is desired, that the tar is distilled until only coke remains in the still. The coke, which is a very pure carbon, finds a sale for purposes similar to those for which retort carbon is used. The creosote, in consequence of the high temperature used in this distillation, is very high boiling and has a high specific gravity. There are at least two plants in this country which make special oils in this way.

Creosote oil, as it appears on the market, is not always a product obtained by the straight distillation of tar. It is frequently mixed with other products of coal tar, which are not of any value in other industries. For instance, the oil obtained by pressing the anthracene cake frequently finds its way to the creosote-oil tank, as does also the phenanthrene which results from the purification of the anthracene cake. The high-boiling oils known as carbolineums are, essentially expressed, "anthracene oils." In this country, tar is sometimes added to light creosote oils to raise their gravity. This tar may be either water-gas tar or low-carbon coal tar. The light creosote oils are sometimes redistilled, to remove part of the light oil and naphthalene and thus produce an oil that will fulfill specifications otherwise not met by the total distillate.

The amount of material classed under "creosote" that was produced, imported, and used in this country is shown by Table 7, covering the last nine years. These figures include not only straight distilled products of coal tar, but, in all probability, water-gas-tar creosotes, mixtures of water-gas-tar creosotes and coal-tar creosotes, and mixtures of either or both with coal tar, either refined, filtered, or crude, as well as mixtures of either or both with water-gas tar. No estimate of the amount of these mixtures can be made.

TABLE 7.—*Relative quantities of domestic and imported creosotes used by the treating plants of the United States, 1909 to 1918 (1).*

Year.	Total creosote used.	Domestic creosote.	Per cent of total.	Imported creosote.	Per cent of total.
	<i>Gallons.</i>	<i>Gallons.</i>		<i>Gallons.</i>	
1909	51,426,212	13,862,171	27	37,569,041	73
1910	63,266,271	18,184,355	29	45,081,916	71
1911	73,027,335	21,510,629	29	51,516,706	71
1912	83,666,490	31,135,195	37	52,531,295	63
1913	108,373,359	41,700,167	38	66,673,192	62
1914	79,334,606	28,026,870	35	51,307,736	65
1915	80,859,442	¹ 43,358,435	54	37,501,007	46
1916	90,404,749	² 46,754,818	52	43,649,931	48
1917	75,541,737	³ 57,282,596	76	18,259,141	24
1918	52,776,386	⁴ 50,610,650	96	2,165,736	4

¹ 41,333,890 gallons coal-tar creosote and 2,024,545 gallons water-gas tar.² 45,318,735 gallons coal-tar creosote and 1,436,083 gallons water-gas tar.³ 54,305,204 gallons coal-tar creosote and 2,977,392 gallons water-gas tar.⁴ 47,787,998 gallons coal-tar creosote and 2,822,652 gallons water-gas tar.

PART II. EXPERIMENTAL COMPARISON OF AUTHENTIC SPECIMENS OF CREOSOTE.

CHAPTER I. COLLECTING AND TESTING THE SPECIMENS OF CREOSOTE.

In the early part of 1911 experiments were begun at the Forest Products Laboratory for the purpose of obtaining data on the chemical and physical properties of authentic coal-tar and water-gas-tar creosotes in order to check up the results previously obtained by the laboratory, and also of determining how wide a variation in these properties may be expected from the different retorts or ovens under various conditions of heating and with the different kinds of coal used. At the time the experiments were begun the latest available figures for the production of tar were the following:

	Gallons.
Gas-house tar, 1908.....	58, 541, 000
Coke-oven tar, 1909.....	60, 126, 000
Water-gas tar, 1908.....	14, 700, 000

The production of gas-house tar and that of coke-oven tar were, therefore, about equal, and the water-gas tar produced was about one-fourth of the product of the gas-house industry.

MATERIAL USED.

In collecting the samples of coal tar for this work the following points were taken into consideration: First, the type of retort or by-product oven employed; second, the kind of coal used; third, the temperature of coking. Circular letters were sent out to all the gas plants in this country that were manufacturing over 20,000,000 cubic feet of coal gas a year, asking for information on these points. Over 75 per cent of the companies replied. Of a total of 91 gas houses using coal, 82 used the horizontal retort, 7 the inclined retort, and 2 the vertical retort. Westmoreland coal was used by 19 of these, Youghioghenny by 35, Alabama by 7, Tennessee by 2, and the remainder were using mixtures of coal from different localities, chiefly mixtures of Westmoreland, Youghioghenny, and West Virginia, with other coals. Very few replies were made concerning the temperature, except in such terms as white, orange, cherry, and red heat. In the few instances given, the temperatures ranged from 1,800° F. (982° C.) to 2,700° F. (1,482° C.).

In view of the predominance of Youghioghenny and Westmoreland coal in the gas-house industry, it was decided to take six samples of

tar from Youghiogheny and five from Westmoreland. In addition, three samples were taken from plants using Alabama coal and three from plants using mixed coal in the horizontal retorts. Certain earlier investigations at the Forest Products Laboratory had shown that the tar produced from at least one inclined-retort plant had certain peculiarities which at the time put it under the suspicion of having been contaminated with other tars. For this reason it seemed desirable to visit as many of these plants as could be conveniently reached and determine whether these differences in properties were peculiar to the one plant or whether they were characteristic of inclined-retort tar. Six samples of this tar were collected. At the time of the collection only two plants were using the vertical retort, and one of these was not in active operation. Therefore, only one sample of vertical-retort tar was taken. Approximately one-half of the by-product coke-oven plants then existing were visited. They included six Semet-Solvay, five Otto or Otto-Hoffman, and one Koppers oven plant.

Table 8 shows the maximum temperature at which the coal was coked, and the specific gravity and free-carbon content of the tar produced by the different types of oven, as determined by the Office of Public Roads in 1912.

TABLE 8.—*Specific gravity and free-carbon content of various coke-oven tars.*

Type of oven.	Maximum temperature of coal (° C.).	Specific gravity of tar at 25° C.	Free-carbon content.	Type of oven.	Maximum temperature of coal (° C.).	Specific gravity of tar at 25° C.	Free-carbon content.
Koppers.....	1,388	1.171	3.89	Otto-Hoffmann....	1,200	1.160	13.94
Do.....	880 to 950	1.169	2.73	Do.....	1,000	1.214	14.05
Semet-Solvay.....	950 to 1,150	1.195	7.76	Do.....	-----	1.143	10.81
Do.....	950 to 1,150	1.206	8.77	Do.....	1,111	1.160	8.37
Do.....	950 to 1,150	1.176	7.14	United Otto.....	1,444	1.191	7.89
Do.....	950 to 1,150	1.168	6.10	Do.....	1,222	1.179	8.49
Do.....	950 to 1,150	1.173	4.71	Do.....	1,222	1.133	5.21
Do.....	950 to 1,150	1.191	7.49	Do.....	1,222	1.176	10.53
Do.....	950 to 1,150	1.169	6.56	Do.....	-----	1.195	12.18
Do.....	950 to 1,150	1.159	6.07	United Otto and Otto-Hoffmann..	833 to 1,055	1.182	11.30
Do.....	950 to 1,150	1.181	8.85	Do.....	1,111	1.211	12.40
Do.....	950 to 1,150	1.159	5.05	United Otto and Rothberg.....	1,000	1.210	16.80
Do.....	950 to 1,150	1.141	3.96				
Do.....	950 to 1,150	1.175	6.90				

Attention is particularly directed to the low carbon content of these tars. Of the 26 listed, only 8 have more than 10 per cent.

A total of 36 specimens of coal tar reached the Forest Products Laboratory in good condition. Three specimens were lost through leakage in transit. Table 9 gives the type of retort or oven from which the specimen tars were obtained, the kind of coal used, and a rough measure of the temperature used in coking. The temperatures shown for by-product tar were those given in Circular 97 of the Office of Public Roads for the same plants. For the most part

the coals used in by-product ovens were a mixture of two or more coals, as is customary in this industry.

These samples were collected from the States of Rhode Island, Massachusetts, Connecticut, New York, Pennsylvania, Delaware, Maryland, Ohio, Illinois, Missouri, Wisconsin, and Alabama. They represent fairly this country's total production of coal tar.

TABLE 9.—*Coal tars used in experimental work.*

Tar number.	Kind of retort or oven.	Kind of coal.	Temperature.
1	Horizontal retort	Youghiogeny	White to cherry.
2	do.	do.	Cherry.
3	do.	do.	Do.
4	do.	do.	Do.
5	do.	do.	Orange.
6	do.	do.	Cherry.
7	do.	Westmoreland	Red.
8	do.	do.	Cherry.
9	do.	do.	Do.
10	do.	do.	White.
11	do.	do.	White to Cherry
12	do.	Alabama	Orange.
13	do.	do.	Do.
14	do.	Mixed	Cherry.
15	do.	do.	Orange.
16	do.	do.	Red.
17	Inclined retort	Westmoreland	Cherry.
18	do.	do.	Do.
19	do.	do.	Do.
20	do.	do.	Orange.
21	do.	Mixed	Cherry.
22	do.	do.	Do.
23	Vertical retort	Westmoreland	Do.
24	Otto oven	Native	1,100 to 1,300° C.
25	do.	Fairmont	
26	do.	Mixed	
27	do.	do.	
28	do.	do.	
29	Semet-Solvay	Westmoreland and Pocahontas	
30	do.	Mixed	
31	do.	do.	
32	do.	West Virginia	
33	do.	Mixed	
34	do.	Alabama	
35	Koppers	do.	

The samples of water-gas tar were taken for the most part at plants making both water gas and coal gas, but a number were collected from plants using only the water-gas process. They were taken from the same States as the coal-tar samples, and fairly represent the production of this kind of tar east of the Mississippi River, if not of the whole country. Table 10 indicates the number of the water-gas tars, the kind of oil used, the temperature regulation, and whether the plant manufactures coal gas also.

TABLE 10.—*Water-gas tars used in experimental work.*

Tar number.	Kind of oil used.	Temperature regulation.	Plant manufactures coal gas also.
37	Gas	None	No.
38	do	do	No.
39	do	do	Yes.
40	do	do	Yes.
41	do	do	Yes.
42	do	do	Yes.
43	do	do	Yes.
44	do	Yes (1,360° to 1,400° F.)	Yes.
45	do	No.	Yes.
46	do	Yes (1,350° to 1,400° F.)	Yes.
47	do	No.	No.
48	do	do	No.
49	do	Yes (1,300° to 1,400° F.)	No.
50	do	do	No.
51	do	do	Yes.
52	do	No.	No.
53	do	Yes (1,300° to 1,400° F.)	Yes.
54	do	No.	Yes.

The apparatus used for distilling the tars is shown in figure 11. The still proper, *A*, consists of an ordinary 2-gallon cast-iron pot still with a wide top clamped gas-tight. This still was mounted in an iron framework and suitably shielded with asbestos boards. It was tapped at the bottom, and a connection made with $\frac{1}{4}$ -inch gas pipes, *B*, to permit the entrance of more tar and to serve as an inlet for air. This pipe was also provided with a union, so that after distillation the upright part could be turned down and serve as an exit for the molten pitch. The gooseneck on the still was changed somewhat, in order to admit of the use of a thermometer *T*, and also to provide for a peep sight *P*, at the top of the still. In making the peep sight, two pieces of brass tubing were threaded to fit a $\frac{3}{4}$ -inch cross. In the threaded ends of these tubes were cemented two pieces of glass tubing containing a flattened bulb at the end. When the brass tubes were inserted in their proper places, the two glass surfaces were from one-fourth to one-half inch apart. This peep sight provided an indication as to the working of the still. One of the greatest difficulties encountered in the distillation of the tar was the frothing over of the still caused by the presence of moisture. When this occurred, the peep sight was blackened, and the operator had a fraction of a second in which to turn off the gas and air and adjust the three-way cock *E*, to catch the undistilled tar in a separate container, so that it could be returned to the still by means of a separatory funnel *F*, at the top of the inlet tube. It was found by experiment that the easiest way to distil coal tar was to use at the start only one-half of the amount of material for a full charge, and by careful heating and by stirring with air to raise the temperature, as recorded by the thermometer at *T*, to about 110° C., and not above 120° C. When this point was reached, the rest of the tar for a

full charge was admitted along with air in a slow stream through the separatory funnel *F*. In this way only very small quantities of water were present at one time in the still, and the slow drying that would otherwise be necessary was avoided and at the same time the danger from frothing was eliminated. Air-cooled glass condensers *D* were used throughout the work, but they were supplemented by a water-cooled reflux condenser *R* at the receiver during the early stages of the distillation. The apparatus could be used for distillation in a stream of air, or without air, or with steam, as the case might require, and could be changed from one system to another during the distillation.

APPARATUS AND METHOD USED IN TESTING THE CREOSOTES.

APPARATUS FOR DISTILLING TARS.

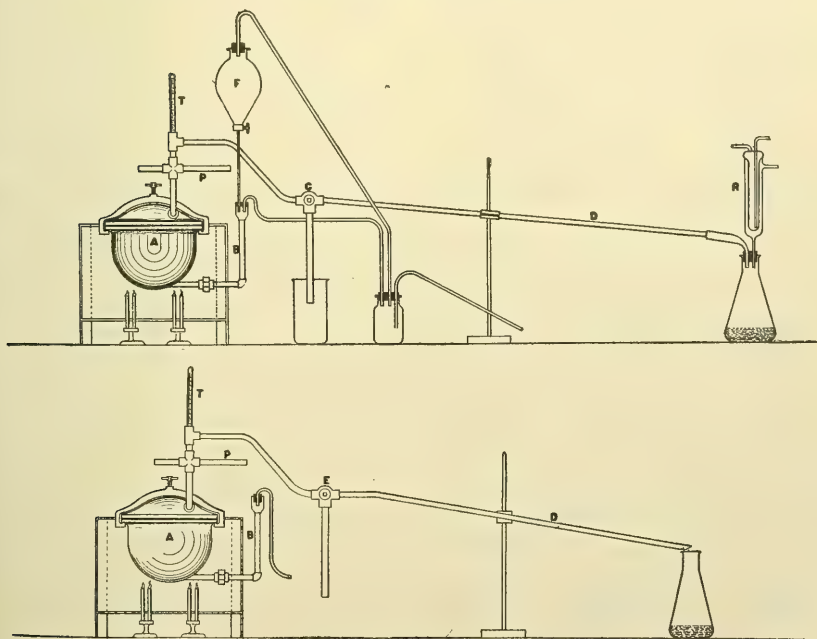


FIG. 11.—Apparatus used for distilling tars.

For the reader's convenience, a complete description of the apparatus and methods used in the testing of the creosotes is given in detail, although part of it has been published before. (12)

Distillation test.—In all distillations a Hempel flask was employed. Hempel flasks are usually made from Jena glass or its equivalent. The bulb is of such a capacity that, when it is filled to the bottom of the neck, it holds 500 cubic centimeters, a variation of 25 cubic centimeters being allowed. The neck of the flask is 1 inch in diameter and $7\frac{1}{2}$ inches long from the top of the bulb to the delivery tube and extends 3 inches above the delivery tube. The delivery tube makes

an angle of 75° with the neck of the flask, and is one-fourth inch in diameter and $8\frac{1}{2}$ inches long. The neck of the flask is constricted at its junction with the bulb to three-fourths inch in diameter. This constriction is made so that a loose plug of wire, preferably platinum, may be dropped into the neck to support a column of glass beads. In making the plugs used at the Forest Products Laboratory, two circles of heavy wire were fastened together at right angles to each other, and another circle of heavy wire was fastened to them in such a manner that the plane of this circle was perpendicular to the plane of the other two. Using these three circles as a framework, wire was used to fill up the spaces on the surface of the sphere and form a network through which the beads would not slip. Another device which serves the purpose equally well may be made from perforated sheet metal bent in the shape of a truncated cone. In constructing these, a circle $1\frac{1}{2}$ inches in diameter was cut from perforated sheet brass of 23 B. S. gauge, having 23 perforations 0.023 inch in diameter to the linear inch. On the outside of the circle was cut a number of irregular notches one-fourth inch across and one-fourth inch deep. A sector was next cut from the whole, so that the remaining portion contained about two-thirds of the total area of the circle. The edges of this section were then drawn together and fastened by a wire in the form of a cone. Lastly, a small weight was hung from the center of the cone like the clapper in a bell, so that the cone would stand upright when it was dropped into the flask. This would support the column of beads fully as well as platinum wire, and had the advantage of being somewhat cheaper.

The bead column is composed of approximately 200 glass beads, but its height should be kept constant at 5 inches with a variation of not more than one-fourth inch. Some previous work by the Forest Products Laboratory on the distillation of turpentine (Forest Service Bulletin 105) has shown that the most important factor in the use of a Hempel column in distillation is the height of the bead column. The diameter of the column and the size of the beads have apparently but little effect, so far as the efficiency of separation is concerned, but do affect the speed at which the distillation can be run. If the same speed and the same height are used, the results obtained are identical, irrespective of the size of the beads or the diameter of the bead column, provided that the speed is not great enough to prevent the condensed liquid from returning to the flask.

The distillations were run at a rate as nearly uniform as possible. The speed of the dropping was timed by the use of a metronome set at 90 a minute and kept as near this rate as possible. At no time, however, was it allowed to exceed 120 drops or to go below 60 when once the distillation had been started.

The flask in position for distillation is supported on an asbestos board in which a hole has been cut almost as large as the great diameter of the bulb. The outline of this opening is irregular to permit the flame to play about the bulb. No wire gauze is used, for there is no danger of breakage so long as the flame does not come in contact with dry glass. The portion of the bulb above the asbestos board and below the Hempel column is protected from drafts by an asbestos box. No protection is given to the Hempel column unless the condensation becomes so great that the column begins to fill, and then it is surrounded by an asbestos box sufficiently large to prevent any portion of it coming in contact with the glass. The condensers used are ordinary glass tubing about one-half inch in diameter, drawn down at one end to about one-fourth inch and flanged at the other to receive a cork stopper. The length is approximately 8 inches. This has been found to be sufficient to condense all of the lighter oils but not sufficiently long to cause much solidification of the higher distillates in the tube. If solidification should occur, it is always melted out before the fraction is taken.

The thermometers used in this work were made of Jena borosilicon glass and were filled above the mercury column with carbon dioxide at a pressure of approximately 15 atmospheres. They read from 180° to 550° C. and were standardized either by the Bureau of Standards or by the German Physikalisch Technische Reichsanstalt. Corrections were made for the slight inaccuracy of the thermometers and also for the emergent stems. This latter correction is not usually made in creosote distillation, and would not be necessary if a standard thermometer were used for all such distillations and if the length of the emergent stem were the same in all cases. At the time this work was started no standard thermometer for creosote distillation had been adopted or even proposed by the various associations interested in wood preservation. The correction was necessary, therefore, as only by this method could the data here presented be compared with data in the collection of which thermometers of different lengths had been used.

For those who are not familiar with the emergentstem correction, the following explanation of its meaning and use is given. Mercurial thermometers are usually standardized with the whole of their mercury column at the same temperature as that of the bulb. This is possible only when the total length of the thermometer is bathed in the heated vapors or liquid. If this is impossible, then the thread of mercury is cooler than the bulb, and an error is introduced which makes the observed reading too low. If the difference between the temperature of the stem and bulb is small, this error is negligible; but if the difference is large, and the length of the emergent stem is great, the error becomes a factor of considerable importance, and

may be as great as 10°C . at the temperature used in distilling creosote oil. The formula for making the correction for this error is given in various ways. That adopted by the United States Bureau of Standards is $F (T-t) N$, in which T equals the observed reading of the thermometer; t , the average temperature of the emergent stem, obtained by placing another thermometer with its bulb at the center of the emergent stem; N , the number of degrees emergent, and F a factor for the thermometer depending upon the difference of expansion of glass and mercury. This factor varies from about 0.00015 to 0.00017; for Jena borosilicon glass the factor is 0.000158. Some idea of the size of these corrections may be obtained from Table 11.

TABLE 11.—*Corrections for emergent stem.*

T .	t .	N .	Correc- tion.	T .	t .	N .	Correc- tion.
200	-----	-----	-----	270	52.0	70	2.4
210	42	10	0.3	280	53.5	80	2.9
220	43.5	20	.6	290	55.0	90	3.4
230	45.0	30	.9	300	57.0	100	3.9
240	47.0	40	1.2	310	58.5	110	4.4
250	48.5	50	1.6	320	60.0	120	5.0
260	50.0	60	2.0	360	70.0	160	7.5

It is obviously impossible to perform the calculations necessary for this correction and at the same time watch a distillation in which fractions are being taken every 10 degrees. In this work, therefore, the position of each thermometer was fixed in respect to the distilling vessel and a table was worked out with different values for t . One of these tables is shown below (Table 12). It also makes correction for the errors in the thermometer caused by the irregularities in its construction.

TABLE 12.—*Emergent-stem corrections used with thermometer No. 1.*

Temp- erature desired when cor- rected.	Temperature to be read when—				Temp- erature desired when cor- rected.	Temperature to be read when—			
	$t=60$.	$t=70$.	$t=80$.	$t=90$.		$t=60$.	$t=70$.	$t=80$.	$t=90$.
$^{\circ}\text{C}$.	$^{\circ}\text{C}$.	$^{\circ}\text{C}$.	$^{\circ}\text{C}$.	$^{\circ}\text{C}$.	$^{\circ}\text{C}$.	$^{\circ}\text{C}$.	$^{\circ}\text{C}$.	$^{\circ}\text{C}$.	$^{\circ}\text{C}$.
180	180.9	-----	-----	-----	265	263.1	263.2	-----	-----
205	205.9	-----	-----	-----	275	272.5	272.5	-----	-----
215	215.7	-----	-----	-----	285	281.8	281.9	-----	-----
225	225.2	-----	-----	-----	295	291.2	291.4	282.0	-----
235	234.8	-----	-----	-----	305	300.6	300.7	300.9	301.0
245	244.2	-----	-----	-----	315	310.2	310.3	310.5	310.6
255	253.7	-----	-----	-----	330	324.4	324.6	324.7	324.9

With this table before the operator, it was necessary only to determine t by a small thermometer hung in the air beside the standard and, by reference to the table, determine the exact point at which the cut should be made. The differences in these corrected readings

and those which would have been obtained under the same conditions by a thermometer complying with the specifications adopted by the American Wood Preservers' Association in 1912 are shown in Table 13.

TABLE 13.—*Comparison of temperature readings of corrected thermometers and standard thermometers of the American Wood Preservers' Association, uncorrected.*

Cor- rected temper- ature.	Stand- ard ther- momet- er, A. W. P. A., uncor- rected.	Differ- ence.	Cor- rected temper- ature.	Stand- ard ther- momet- er, A. W. P. A., uncor- rected.	Differ- ence.
° C.	° C.	° C.	° C.	° C.	° C.
180	178.8	1.2	265	260.2	4.8
205	203.0	2.0	275	269.7	5.3
215	212.7	2.3	285	279.1	5.9
225	222.2	2.8	295	288.4	6.6
235	231.8	3.2	305	297.7	7.3
245	241.3	3.7	320	311.7	8.3
255	250.8	4.2			

The fractions taken in this work are those given in Tables 12 and 13 in the first column. Two hundred and fifty grams of oil were used for a distillation, and the percentage weight of each fraction was determined to the nearest one-tenth of 1 per cent.

Index of refraction test.—The nature of the refraction test may be briefly described. When a ray of light passes from one medium to another of different density, it is bent out of its course or refracted. A familiar example of this refraction is shown by the appearance of piling just at the water line. Both above and below the water line the pile appears straight, but that portion of the pile under water appears to be nearer than the portion above. This is because of the difference in the refraction of light in air and in water. The refraction of light varies with every pair of media through which the light passes; but, if some medium is taken as a standard, then all measurements may be referred to it. The standard adopted is air. The refraction of light is measured by the angle through which the beam is bent in passing from air into the other medium. This measurement may be made by degrees and minutes or, for convenience, in what is known as the index of refraction. The index of refraction is the sine of the angle of incidence divided by the sine of the angle of refraction. The most convenient instrument for measuring this property is known as the Abbé refractometer, a view of which is shown in figure 12. It consists essentially of a split prism, *AB*, surrounded by heating chambers, all of which are mounted on a movable carriage, which in turn is connected to a lever carrying the reading glass *L*, over the fixed scale *J*. Above this split movable prism is mounted a spyglass, *F*, which is held in a fixed position in respect to

the scale *J*. The prism *AB*, being split, may be opened to receive the liquid material between the two faces, and it is this minute quantity of oil or other substance which we use in measuring the index of refraction. In operation light falling on the mirror is reflected into the prism *AB*. After passing through *B*, if no material is contained between the prism faces *A* and *B*, the light is totally reflected by the polished surface of *A*, and no light can pass into the spyglass above. If material is present, the light is refracted by this material, and this refracted light passes through the prism *A* into the spyglass, where it appears as a light portion above a shadow. The lever carrying the glass *L* and the split prism are then moved until the junction of light and shadow appears to be on the cross-

hairs with which the spyglass is provided. The index of refraction is then read from the scale *J* by means of the reading glass *L*. No calculations are necessary.

With pure material the index of refraction has been used in determining the structure and character of carbon compounds, but with creosote it is merely a measure of a physical property of the oil which is easy of attainment. The same combinations of the same substances will always give the same index of refraction at a fixed temperature; but it does not always follow that, because the same index of refraction is obtained, two oils are of identical composition. The refractometer finds a very large use in commercial

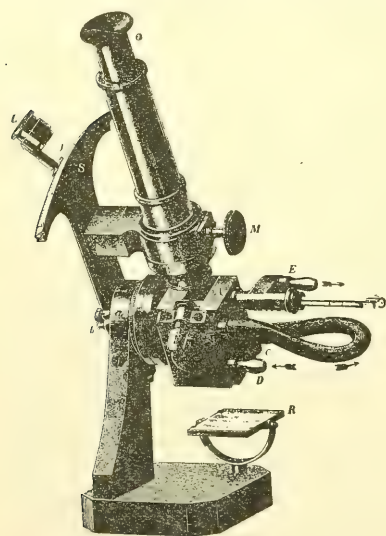


FIG. 12.—The Abbé refractometer.

testing, particularly of oils, fats, and low-melting waxes, because exceedingly rapid as well as accurate measurements can be made.

The index of refraction was taken on all fractions above 235° C., up to the point at which the distillate was no longer liquid at 60° C., the temperature at which these measurements were made. The values for the index of refraction are affected by the temperature to a considerable extent, and the higher the temperature the lower the index of refraction. It is, therefore, necessary either that measurements of this physical property be taken at a constant temperature or else that a correction be applied to change the observed reading to that at a standard temperature. The temperature factor for changing index of refraction values varies with different substances; hence, correction factors for creosote would be as

great in number as the number of fractions taken. All readings of the index of refraction were, therefore, taken at the standard temperature of $60^{\circ}\text{C}.$, a possible variation of 1° being permitted. This variation is corrected by the use of the factor 0.00036 per degree. The factor is added when the actual temperature is above $60^{\circ}\text{C}.$, and subtracted when it is below.

Specific-gravity test.—The specific gravity of the fractions was taken at $60^{\circ}\text{C}.$ by means of a Westphal balance having a displacement of approximately 2 cubic centimeters. Here, again, as in the index of refraction, the factor for changing the readings at one temperature to those of another temperature is unknown; consequently, they were taken at exactly $60^{\circ}\text{C}.$, this temperature being maintained by means of a water-bath whose temperature was controlled to one-tenth of a degree. The density of the fractions was referred to the density of water at $60^{\circ}\text{C}.$, and, as the density of water has been very accurately determined (13), the readings given in this paper may easily be transferred to those at any other temperature, if that is desired. The values for $60^{\circ}\text{C}.$ given in this publication are higher than they would be if water at $15^{\circ}\text{C}.$ were taken as unity, but may be calculated to that standard by multiplying by 0.986. In a few cases the volume of the fractions was too small to make possible the determination of the specific gravity. In such cases two adjacent fractions were mixed, and the gravity was recorded as the average of the two. This made possible a record of the gravity of fractions which would otherwise have been omitted.

Sulphonation test.—The sulphonation test used was that described in Forest Service Circular 191. Ten cubic centimeters of the fraction of creosote to be tested are measured into an ordinary Babcock milk bottle. To this is added 40 cubic centimeters of 37/N sulphuric acid, 10 cubic centimeters at a time. The bottle with its contents is shaken for 2 minutes after each addition of 10 cubic centimeters of acid. After all the acid has been added, the bottle is kept at a constant temperature of 98° to $100^{\circ}\text{C}.$ for one hour, during which time it is shaken vigorously every 10 minutes. At the end of the hour the bottle is removed, cooled, filled to the top of the graduation with ordinary concentrated sulphuric acid, and then whirled for 5 minutes in a Babcock separator. The unsulphonated residue is then read off from the graduation. The readings from the major graduations multiplied by two give the percentage of sulphonated residue by volume. Each major graduation is equal to one-fifth of a cubic centimeter, and the minor graduations are sometimes equal to one-twenty-fifth and sometimes to one-fiftieth of a cubic centimeter.

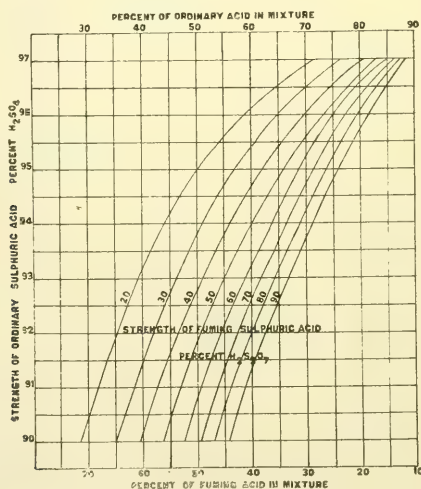
In well-equipped laboratories the usual steam-jacketed ovens capable of maintaining a temperature of 98° to $100^{\circ}\text{C}.$ will keep the reaction mixture of the sulphuric acid and creosote at the proper tem-

perature. It frequently happens, however, that creosotes are analyzed in laboratories equipped for that purpose only; for such an equipment a special steam-bath or oven may be made by any tin-smith at small cost. It is essential that the chamber be of sufficient size to contain the Babcock bottle completely. Otherwise the exact dimensions of the steam bath are unimportant. The 37/N sulphuric acid is prepared by mixing fuming sulphuric acid with enough ordinary sulphuric acid so that the finished mixture will contain 80.1 per cent SO_3 . Fuming sulphuric acid may be purchased in different concentrations, and there are two methods in common use for recording the strength. This is sometimes given in terms of free SO_3 , and at other times in terms of $\text{H}_2\text{S}_2\text{O}_7$. Table 14 shows the relation between the two methods of nomenclature.

TABLE 14.—*Concentration of SO_3 in fuming sulphuric acid.*

Per cent total SO_3 .	Per cent $\text{H}_2\text{S}_2\text{O}_7$.	Per cent free SO_3 .	Per cent total SO_3 .	Per cent $\text{H}_2\text{S}_2\text{O}_7$.	Per cent free SO_3 .	Per cent total SO_3 .	Per cent $\text{H}_2\text{S}_2\text{O}_7$.	Per cent free SO_3 .
81.8	0	0	85.1	40	19	88.4	80	37
82.6	10	5	85.9	50	23	89.2	90	41
83.4	20	10	86.7	60	28	90.0	100	46
84.2	30	14	87.5	70	32			

The proper proportion in which to mix ordinary concentrated sulphuric acid with fuming sulphuric acid ($\text{H}_2\text{S}_2\text{O}_7$) is shown by figure 13.

FIG. 13.—Proportion of fuming sulphuric acid $\text{H}_2\text{S}_2\text{O}_7$ required to raise ordinary sulphuric acid to approximately 37.

Tar acids.—For the most part tar acids were not estimated; when they were, the methods specified by the National Electric Light Association, as given in Part IV, were used.

CHAPTER II. DETERMINING CERTAIN CONDITIONS FOR THE TESTS.

EFFECT OF AIR ON TARS DURING DISTILLATION.

As already mentioned, it is usually considered good practice in this country to blow air through the tar during distillation. This offers an opportunity for chemical reaction which might have a considerable effect on the physical and chemical properties of the creosote. It was therefore essential, before work on authentic material was undertaken, that the effect of blowing air through the tar should be known. A tar was distilled without the use of air and also with the use of air under two pressures chosen at random. The pressure of air was kept constant by suitable valves and was recorded in inches of water. A creosote thus prepared was carefully analyzed, the values of the index of refraction of the fractions being taken as a guide for changes in chemical and physical properties. Figure 14 shows graphically the change produced in the index of refraction when the same tar was distilled without the use of air, with air under a pressure of 7 inches of water, and with the air under a pressure of 14 inches of water. It will be shown later that an increase in index of refraction is accompanied by an increase in specific gravity and a decrease in sulphonation residue.

COMPARISON OF COMMERCIAL CREOSOTES WITH LABORATORY CREOSOTES.

Another point of still greater importance in this investigation was the determination of the differences, if there were any, which existed between creosotes produced from small samples (5 to 10 gallons) of tar in the laboratory and those obtained from the same tar under commercial conditions. Through the courtesy of the Barrett Manufacturing Co., of New York, and the United Gas Improvement Co., of Philadelphia, samples of tar were taken from their stills just before distillation and after thorough mixing. Samples of the creosote were then collected as it came from the still throughout the entire distillation. These samples were used as standard commercial creosotes with which the laboratory creosotes prepared from the same tar were compared.

The effect of blowing air through the tar being known, it was simply a matter of experiment to ascertain an air pressure that would

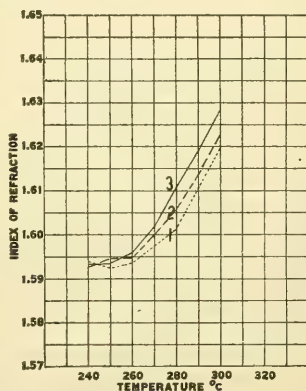


FIG. 14.—Effect of using air during the distillation of tar upon the index of refraction of the fractions of coal-tar creosote.

1. Coal-tar creosote from tar distilled without air.
2. Coal-tar creosote from the same tar distilled with air under 7 inches of water pressure.
3. Coal-tar creosote from the same tar using air under 14 inches of water pressure.

duplicate commercial conditions on a laboratory scale. It was found that air under a pressure of 7 inches completely fulfilled this condition with the still that was used, and that by using this air pressure the creosotes made at the laboratory agreed as closely as could be expected with commercial oils from the same tar. Figure 15 shows the indices of refraction, the specific gravities, and the sulphonation residues of two creosotes, one made at the laboratory and the other at a commercial plant from tar No. 1. Figure 16 shows the index of refraction values and the specific gravities of another pair of creosotes

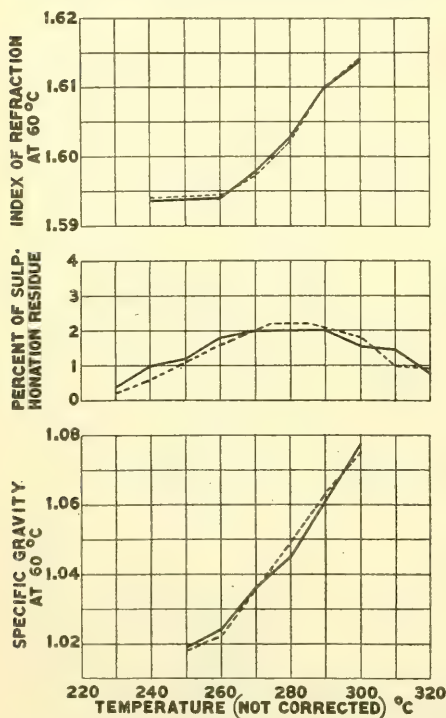


FIG. 15.—Physical constants of two coal-tar creosotes produced from tar No. 1.

Commercial coal-tar creosote—Dotted line.
Experimental coal-tar creosote—Solid line.

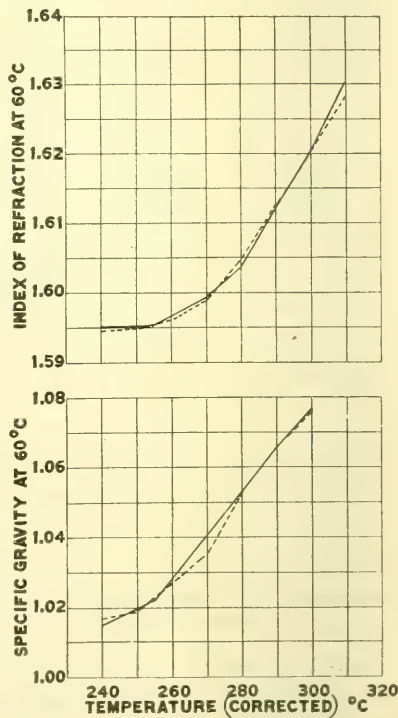


FIG. 16.—Physical constants of two coal-tar creosotes produced from tar No. 2.

Commercial coal-tar creosote—Dotted line.
Experimental coal-tar creosote—Solid line.

produced from tar No. 2, and figure 17 shows the indices of refraction of two other pairs of creosotes made from tars No. 3 and 4, respectively. These figures show that creosotes can be produced from tars in the laboratory in such a way as to duplicate commercial conditions, and can be made as nearly identical as two analyses of the same oil.

In view of the fact, however, that not all tar distillers use air in their operation, it was decided that all work on authentic tars should

be carried out with the use of air under a pressure of 7 inches of water until all the moisture had been expelled from the tar. The rest of the distillation was completed without the use of air. The data thus obtained represent creosote oils that any manufacturer could obtain from the same tar. If there is any difference, the oils are lower in index of refraction and specific gravity, and higher in sulphonation residue than they would have been with the use of air. In other words, any specification that might result from this investigation would be on the safe side and would work no hardship on the manufacturer of creosote oil.

It was a somewhat difficult matter to cut the distillates from the tar in such a manner that an oil could be obtained having a distillation range similar to that of a commercial creosote. In practice, therefore, no attempt was made to separate the light oils from the creosote oils in the distillation from the tar still. The only separation made was the fraction containing the water and the more volatile of the light oils. The total distillate above this point was collected in one container and subsequently distilled from an ordinary flask. All oil coming over below 205°C . was discarded. That boiling from 205° to 235°C . was collected separately. The residue above 235°C . was weighed, and to this was added 25 per cent of its weight of the fraction boiling between 205° and 235°C . In this way the creosotes were made to conform to specification No. 1 of the American Railway Engineering Association so far as distillation limits were concerned.

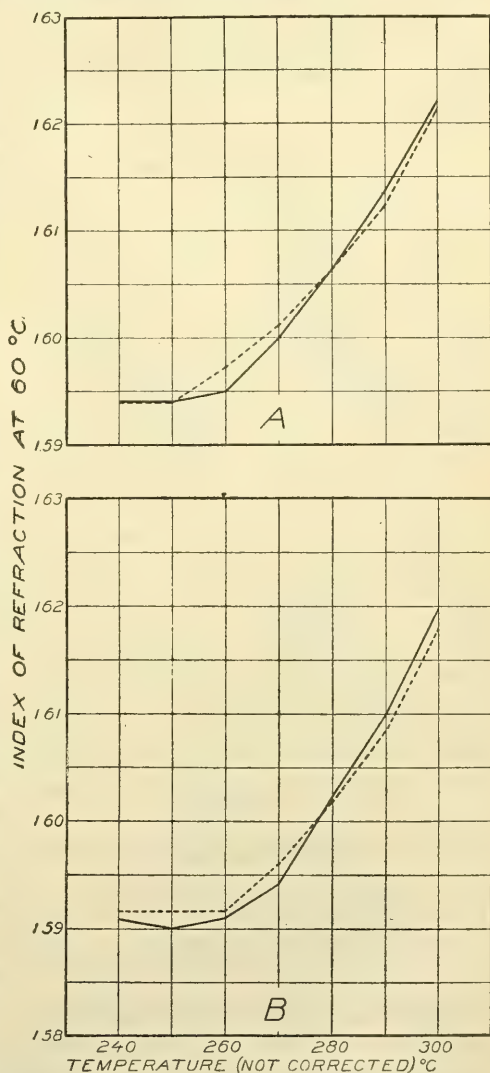


FIG. 17.—Index of refraction values of coal-tar creosotes produced from tars No. 3 and No. 4.

Commercial coal-tar creosotes—Dotted lines.
Experimental coal-tar creosotes—Solid lines.

CHAPTER III. RESULTS OF THE TESTS.

The results obtained by the various tests are given chiefly in the form of curves, which show graphically the similarity or dissimilarity of the creosotes examined. The data are given in tables in the Appendix.

COAL-TAR CREOSOTES.

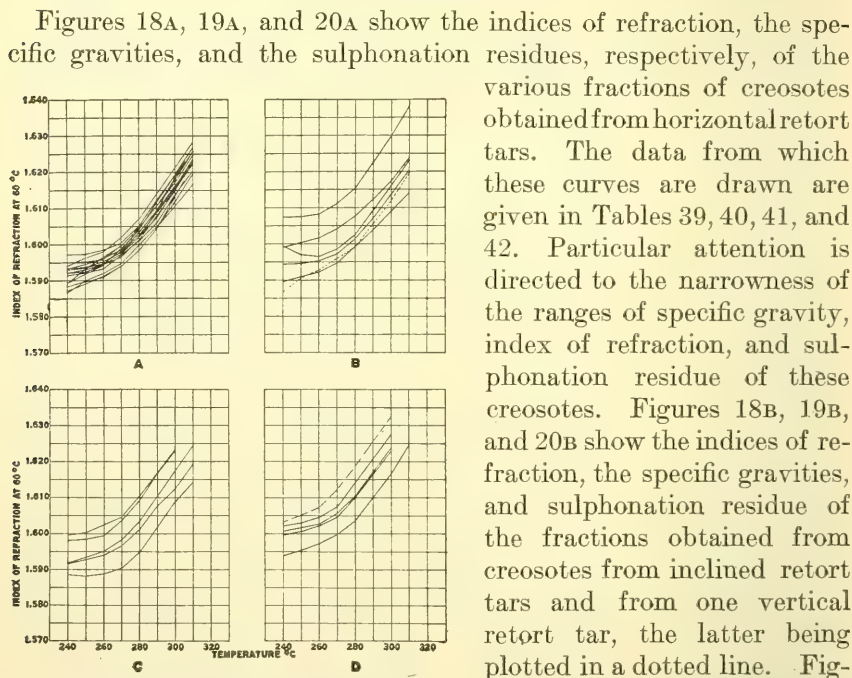


FIG. 18.—Index of refraction values of fractions of authentic coal-tar creosotes.

- A. Horizontal retort-tar creosotes.
- B. Inclined retort-tar creosotes. Dotted line vertical retort-tar creosote.
- C. Semet-Solvay tar creosotes.
- D. Otto-tar creosotes. Dotted line—Koppers-tar creosote.

In these figures the dotted lines are for Koppers tar creosote and the other lines are for Otto tar creosotes. Figure 21 shows summaries of the same results for each type of measurement. The 80° lines represent the range for coke-oven tar creosotes, the 45° lines represent the range of horizontal retort tar creosotes, and the 20° lines represent the range for the inclined retort and vertical retort tar creosotes.

Particular attention is called to figures 20A, 20B, 20C, and 20D, which represent the sulphonation residue of the various fractions. It will be noted that most of the maximum sulphonation residues are

obtained in the fractions boiling between 280° and 290° C., but sometimes not under 300° C. Above and below these points the sulphonation residues decrease. The results shown in these figures seem to indicate that the kind of coal from which the tar is manufactured

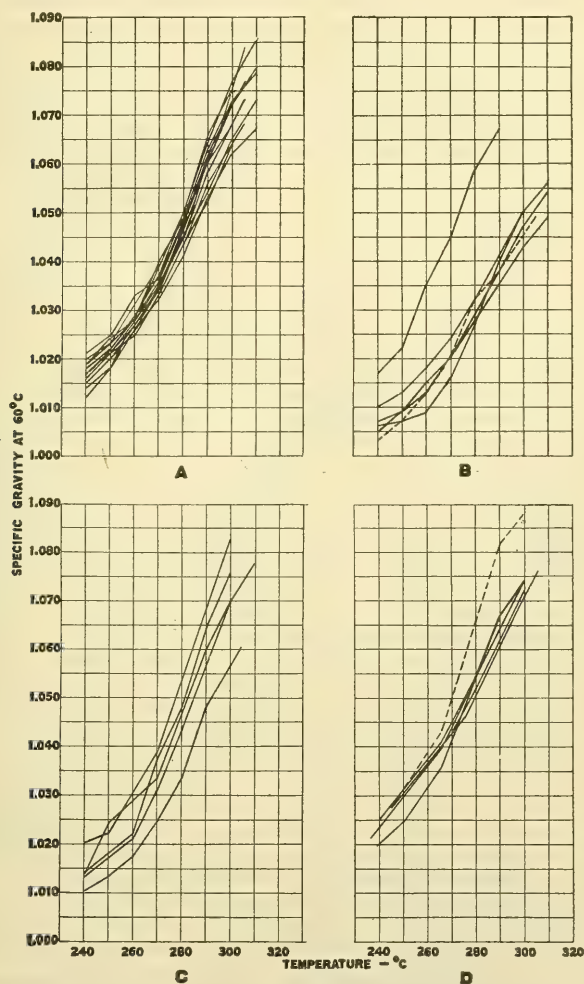


FIG. 19.—Specific gravities of fractions of authentic coal-tar creosotes.

- A. Horizontal-retort tar creosotes.
- B. Inclined-retort tar creosotes.
Dotted line—Vertical-retort tar creosote.
- C. Semet-Solvay tar creosotes.
- D. Otto tar creosotes.
Dotted line—Koppers tar creosote.

has at best only a slight influence on the quality of the creosote produced from coal tar, since in the range shown for horizontal retorts (figs. 18A, 19A, and 20A) Westmoreland, Youghioghenny, Alabama, and Tennessee coals were used, as well as mixtures of unknown or local coals with the above. The wide variation in the properties of coal-

tar creosotes indicated by figures 18 to 20 must, therefore, be due either to the type of retort or to the temperature of coking.

Figure 22 shows two coal-tar creosotes produced from tars from the same mixture of coal and operated under the same management, and as nearly as possible at the same temperature, although one tar was produced in an inclined retort and the other in a horizontal

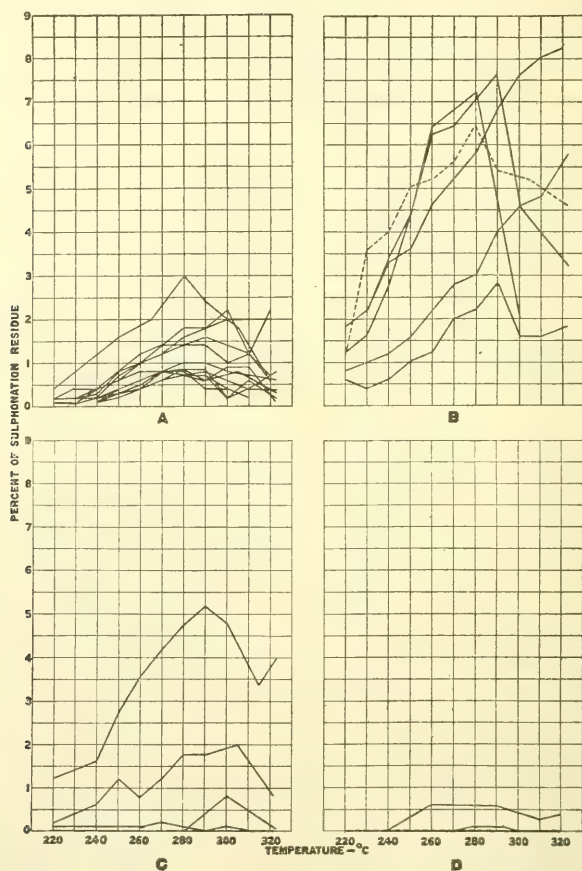


FIG. 20.—Sulphonation residues of fractions of authentic coal-tar creosotes.

- A. Horizontal-retort tar creosotes.
- B. Inclined-retort tar creosotes.
- Dotted line—Vertical-retort tar creosote.
- C. Semet-Solvay tar creosotes.
- D. Otto tar creosotes.
- Dotted line—Koppers tar creosotes.

retort. Figure 23 shows two coal-tar creosotes obtained from the same mixture of coal at different by-product plants which were at the time producing coke in approximately the same length of time, but which employ different types of oven—the Otto-Hoffman and the Semet-Solvay. These figures show the effect of different types of retort when the other two variables are practically the same. It is noted that the results are nearly identical, or, at least, that there

is less difference in the results from using different types of retort or oven than is often shown in the use of different ovens or retorts of the same type. In other words, if the coal and the temperature of coking are the same, the type of retort or oven seems to have little or no effect. This seems to indicate that the producing of highly aromatic coal-tar creosotes is dependent upon the temperature of coking. If this is true, then the method of applying the heat to the retort may have some effect upon the quality of the coal-tar creosote.

According to some researches at the University of Wisconsin (14) on producer gas, tar is formed from coals at comparatively low temperatures, ranging from 200° to 600° C. This is far below the

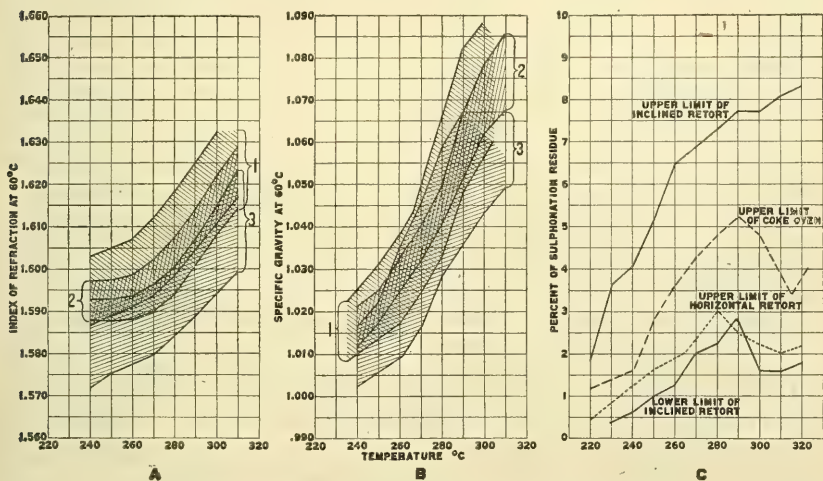


FIG. 21.—Summaries of the physical and chemical measurements of fractions of all authentic coal-tar creosotes.

- A. Index of refraction values.
- B. Specific gravity values.
- 1. Horizontal-retort tar creosotes.
- 2. Coke-oven tar creosotes.
- 3. Inclined and vertical retort tar creosotes.
- C. Sulphonation residues.

temperature of coking in both the by-product and gas-house retorts. Table 8 shows that the temperature of coking in the by-product oven rarely goes below 900° C. and that the average is about $1,000^{\circ}$ C. If tars are produced at temperatures as low as 200° C. and are completely given off from the coal at 600° C., and if the retort is heated to a point as high as $1,000^{\circ}$ C., the tar vapor, as it rises from the coal, must come into contact to a certain extent with a surface heated far above its temperature of formation, when it may, and probably does, undergo a chemical change. It is well known that paraffin-like oils may be obtained if coal is coked at low temperatures. It is also significant to note that in this work the tars produced at the highest temperatures yielded either no coal-tar creosotes at all or else one of

high physical properties and having no sulphonation residues; but that those subjected to lower temperatures yielded coal-tar creosotes having lower index of refraction values and higher sulphonation residues. The inclined-retort tar creosotes were higher in sulphonation residues, and it seems to be almost universally true that, when this type of retort is discharged, there is a small amount of uncoked coal in the charge. In the vertical retort there is less chance for the

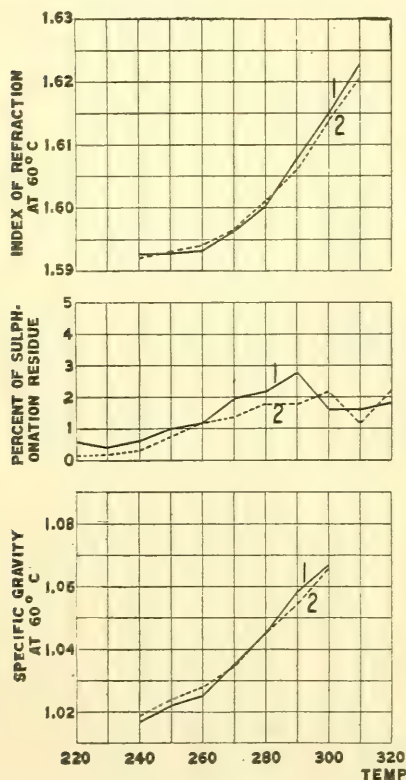


FIG. 22.—Physical and chemical constants of creosotes obtained from tar produced from the same mixture of coal at the same temperature but in different types of retort.
1. Horizontal-retort tar creosote.
2. Inclined-retort tar creosote.

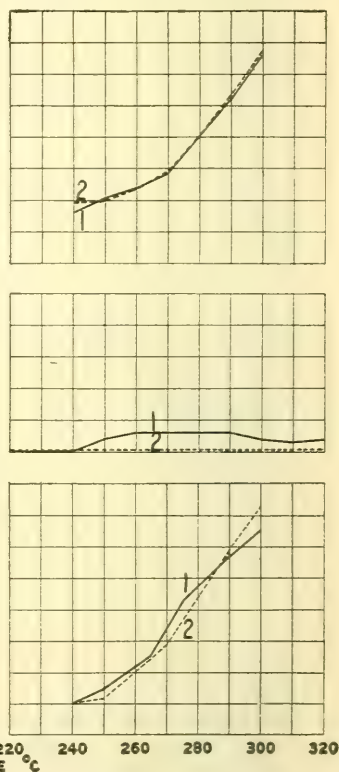


FIG. 23.—Physical and chemical constants of creosotes obtained from tar produced from the same mixture of coal at the same temperature but in different types of oven.
1. Semet-Solvay tar creosote.
2. Otto-Hoffman tar creosote.

gases to come in contact with the heated walls of the chamber unless a fixing chamber is left above the charge. In the by-product ovens the vertically heated ovens usually have a hotter roof than those heated horizontally. Of the six vertically heated by-product ovens only two produced coal-tar creosotes having a measurable amount of sulphonation residue. Of five coal-tar creosotes from horizontally heated ovens all but one had a measurable sulphonation residue. Of the four that had sulphonation residue the oldest plant produced the coal-tar creosotes having the highest sulphonation residue and the

next oldest the next greatest residue. Only one by-product tar creosote exceeded 2 per cent sulphonation residue in any of its fractions.

WATER-GAS-TAR CREOSOTES.

The data obtained on the water-gas-tar creosotes examined are shown in figure 24. In figure 24c attention is again directed toward the fractions from 260° to 300° C., the sulphonation residues being greater in general than in any other fractions obtained in distillation. This is the same as the indication on coal-tar creosotes. Very few data were obtained on the temperatures at which these tars were produced. It is, however, to be noted that the oils showing the highest indices of refraction, the highest specific gravities, and the lowest sulphonation residues were produced at the highest tem-

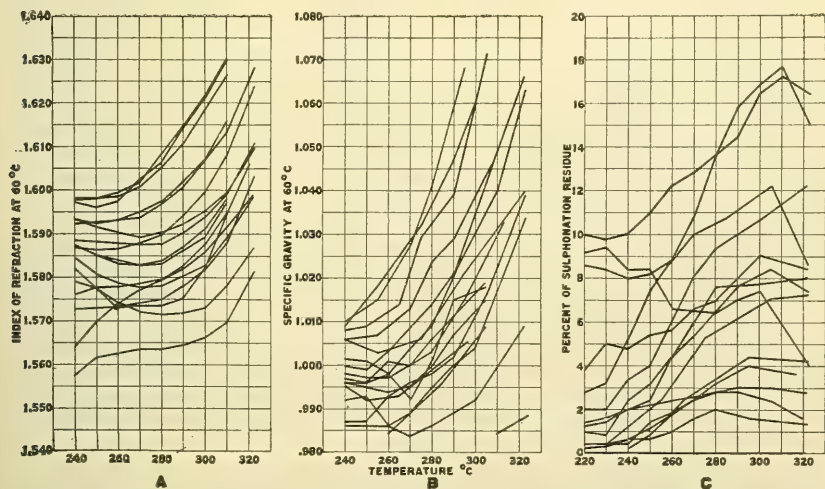


FIG. 24.—Physical and chemical measurements of fractions of all authentic water-gas tar creosote.

A. Index of refraction values.

B. Specific gravity values.

C. Sulphonation residues.

peratures, and in one or two instances the temperature is given at between 1300° and 1400° F., equivalent to 700° to 750° C.

Out of 19 water-gas tars 5, or approximately one-quarter, produced creosotes having 2 per cent or less of sulphonation residue. Eight produced creosotes having 5 per cent sulphonation residue. All of these tars were manufactured in plants that are using temperature regulation in the operation. In this age of scientific management a closer control of manufacturing operations may reasonably be expected, which will result in a probable increase in water-gas tar having a low sulphonation residue.

Statistics on the annual production of water-gas tar are given in Table 6. In 1912 the total production was nearly one-half of the total production of coal tar. The amount sold, however, was only one-quarter of the amount of coal tar sold.

CHAPTER IV. COMPARISON OF THE PROPERTIES OF AUTHENTIC COAL-TAR CREOSOTES WITH THOSE OF AUTHENTIC WATER-GAS-TAR CREOSOTES.

The following curves show the similarities and dissimilarities of the physical properties of all coal-tar creosotes and all water-gas-tar creosotes tested. Figure 25A shows the index of refraction plotted against temperature, in which the lines sloping to the left represent water-gas-tar oils and the lines sloping to the right represent coal-tar

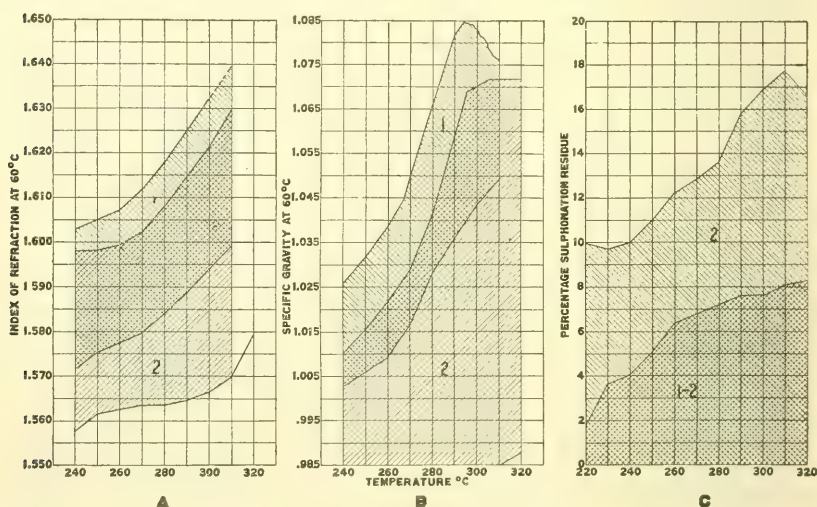


FIG. 25.—Comparison of the physical and chemical properties of the fractions of authentic coal-tar creosotes and authentic water-gas tar creosotes.

- A. Index of refraction values.
- B. Specific gravity values.
- C. Sulphonation values.
1. Ranges of coal-tar creosotes.
2. Ranges of water-gas tar creosotes.

creosotes. Figure 25B shows the same thing for specific gravity, and figure 25C represents the sulphonation residues (but the lines in this case are reversed). It is apparent from these curves that there is no sharp line of demarcation between the physical constants of coal-tar creosotes and of water-gas-tar creosotes. It is to be noted, however, that, whereas the larger number of coal-tar creosotes have a sulphonation residue of less than 3 per cent (see p. 20), the larger number of water-gas-tar creosotes have more than 3 per cent sulphonation residue in one or more of their fractions.

Figure 26 shows the index of refraction values of the fraction 285° to 295° C. taken from 17 coal-tar creosotes and 14 water-gas-tar creosotes, plotted against percentage of sulphonation residue for the

same fractions. The dots represent water-gas-tar creosotes, and the circles represent coal-tar creosotes. Here it is seen that, although in a general way the water-gas-tar creosotes are somewhat lower than the coal-tar creosotes, yet they intermingle to a degree so great that no differentiation could be obtained by this method. Furthermore, the figure indicates very strongly that the sulphonation residues and the index of refraction values are proportional to each other in some inverse ratio. In other words, index of refraction values could be obtained in a very general way by the sulphonation test.

Figures 27A, 27B, 27C, and 27D show the results of plotting specific gravity against index of refraction for the various fractions. Here the specific gravities of water-gas-tar creosotes are lower for the same index of refraction values than are those of the coal-tar creosotes, and there seems to be a somewhat definite line of demarcation between the two. However, the range of coal-tar creosotes and the range of water-gas-tar creosotes are each so much wider than the difference between the two ranges that mixtures of a high-grade water-gas-tar creosote and a high-grade coal-tar creosote would probably be classed as a coal-tar product, and mixtures of a low-grade coal-tar creosote and a low-grade water-gas-tar oil would probably be classed as a water-gas-tar product. In other words, although it is possible by this method to obtain figures showing a difference between pure water-gas-tar products and pure coal-tar products, it would be extremely difficult to say with any degree of authority that a given sample of oil was or was not a mixture of water-gas-tar and coal-tar products.

This method of plotting specific gravity against index of refraction for the individual fractions is the only one that has been found at the Forest Products Laboratory for differentiating water-gas-tar creosotes of low-sulphonation residues from coal-tar creosotes which can be recorded numerically. In addition to this, the odor of water-gas-tar products is characteristic. The recording of this odor, however, involves a large personal equation and is of value to the expert only. It is also well known that water-gas-tar products contain no tar acids or, at any rate, only a small amount, and practically no tar

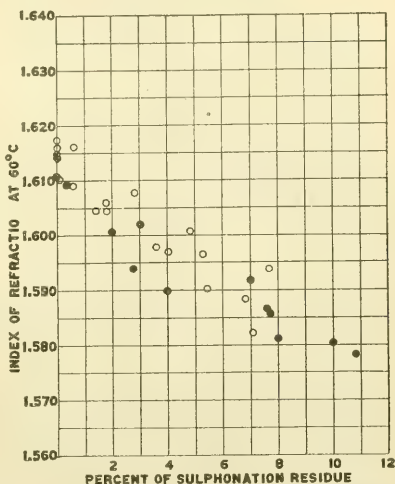


FIG. 26.—The relation between the index of refraction values and the amount of sulphonation residues of fractions of authentic creosotes.
Circles—Coal-tar creosotes.
Dots—Water-gas tar creosotes.

bases. These may easily be added to a water-gas-tar product at slight cost, however, and for this reason their presence is not proof positive that the creosote in which they are found is of coal-tar origin. It was supposed at one time that the color of the fractions was an

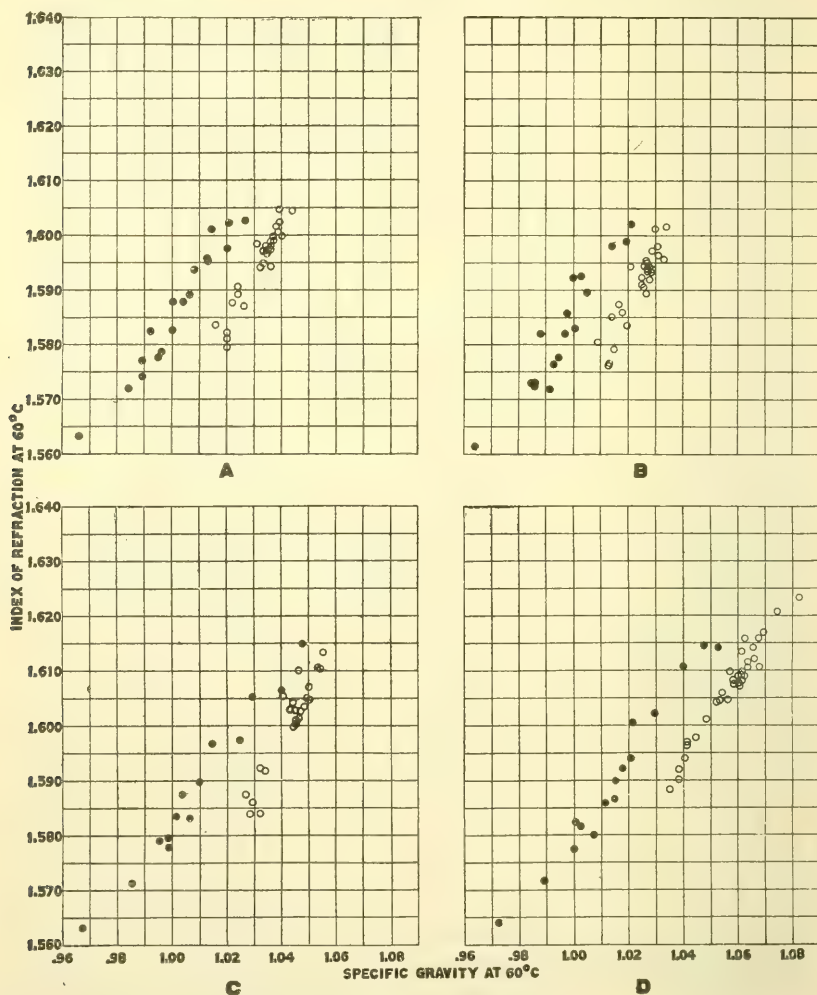


FIG. 27.—Relation between the index of refraction values and the specific gravity of the fractions of creosotes.

Circles—Coal-tar creosotes.

Dots—Water-gas-tar creosotes.

A. Fraction distilling between 255° and 265° C.

B. Fraction distilling between 265° and 275° C.

C. Fraction distilling between 275° and 285° C.

D. Fraction distilling between 285° and 295° C.

indication of a mixture of water-gas-tar oils with coal-tar creosotes. This investigation has shown that the supposed characteristic green color of certain of the fractions is common to all creosotes or oils having a high sulphonation residue, and that this color, therefore, does not indicate a mixture of the two kinds of oil.

PART III. PROPERTIES OF CREOSOTES.

CHAPTER I. COMPOSITION AND CHEMICAL PROPERTIES OF COAL-TAR CREOSOTE.

COMPOSITION OF COAL-TAR CREOSOTES.

The heavy oils of coal tar that are usually known to the trade as creosote oil and carbolineums are in general composed of compounds of the aromatic series and are usually somewhat complex in their chemical structure. The hydrocarbons, that is, those compounds containing only carbon and hydrogen, are represented by members of at least six subdivisions of the aromatic series.

The simplest of these is the benzene series, in which fall such compounds as benzene, toluene, and xylene. These are mainly low-boiling compounds—boiling below 200° C.—and are lighter than water, but, on account of the difficulty in separating these compounds from members of other series having higher boiling points, they may be found in the oils that are heavier than water.¹

The next higher series is probably the indenenes. These also are low boiling, that is, they boil below 200° C., but in all probability they are found in coal-tar creosote.

The naphthalenes, of which naphthalene itself is the most important member so far as creosote oil is concerned, have boiling points between 200° and 270° C. when they are in the pure state. Some of this series are liquid at room temperature, but naphthalene, the parent of the series, is solid at ordinary temperatures, and, if it is pure, melts at 80° C. and boils at 218° C. Naphthalene may be present in almost any proportion in commercial oils. Samples of creosote, examined by the author, have contained as high as 75 per cent of oil boiling below 225° C., of which fully 75 per cent was naphthalene. On the other hand, oils such as the carbolineums contain practically no naphthalene. Acenaphthene might be termed a derivative of naphthalene. It has a somewhat higher boiling point, namely, 275° C. In the pure state this compound is a beautifully crystallized white material, melting at 95° C. It is characterized by its great solubility in hydrocarbon oils, especially those found in creosote; hence it rarely, if ever, crystallizes out from the mother liquor. Experiments at the Forest Products Laboratory seem to indicate that the golden yellow oil, which occurs above the naphtha-

¹ Huntley, in a master's thesis offered at the University of Wisconsin, has shown that oils boiling as low as 137° C. may be obtained from a supposedly high-boiling (295° to 320° C.) fraction of coal-tar creosote. These oils, although small in amount, were in all probability a mixture of xylenes and other of the higher homologues.

lene fraction of creosote oil, is composed chiefly of this compound, mixed with sufficient quantities of other compounds to render it liquid at room temperature.

The highest fractions of creosote are composed chiefly of compounds of the fluorene and anthracene series. The compounds of these series boil from 270° C. to above 400° C. The members of these series that are found in the largest quantity in creosote oil are phenanthrene, anthracene, and fluorene. All of these will crystallize from the creosote oil on standing. The heavy solid matter crystallizing from foreign oils is a mixture of these three compounds with other hydrocarbons and bases. Anthracene is used to a considerable extent in the manufacture of dyes; some of the foreign creosotes may therefore have been robbed of this constituent.

Besides the hydrocarbons, which constitute by far the greater proportion of creosotes, there are a number of compounds containing oxygen which are collectively known as tar acids. These are not true acids in a chemical sense, but are phenols. They have some of the properties that are usually ascribed to acids, but also some of the properties that are characteristic of the alcohols. They are characterized by being extremely toxic to bacteria and fungi as well as to higher organisms. The higher homologues of phenol—the cresols and the xlenols—which are found in creosote, are as destructive as phenol to living organisms, if not more so. As the phenols, cresols, and xlenols may be considered the alcohols or tar acids of benzene, toluene, and xylene, so also in creosote are found compounds of an alcoholic nature known as naphthols, which are derived from the members of the naphthalene series. These, too, are used in medicine, as bactericides and antiseptics. At the present time the total amount of tar acids in creosote oil does not exceed 10 per cent and is usually less than 5 per cent.

Coal-tar creosotes contain also a number of compounds having nitrogen as one of their component parts. These are collectively known in this connection as tar bases. Just as it may be considered that the phenols are obtained from the hydrocarbons by the addition of an alcohol group, so it may be considered that one type of these tar bases is derived from the same hydrocarbons by the addition of an ammonia group. Aniline and the toluidenes are examples of this type of tar base derived from benzene and toluene, respectively. In general, however, this type of nitrogen compound is so low boiling that it is not found to any great extent in coal-tar creosotes. Another type of nitrogen compound contains this element in a much more stable condition. Compounds of this type may be termed cyclic nitrogen compounds, and are represented in coal-tar creosote by the pyridenes, the quinolines, and the acridines. These compounds bear the same relation to one another as benzene, naphthalene, and

anthracene do to one another. In general, the tar bases, particularly the cyclic compounds, are toxic to bacteria and fungi, and have been used as antiseptics in medicine. So far as the author is aware, no systematic tests have ever been made on the amount of tar bases which might be expected in coal-tar creosote. It probably does not, however, exceed the amount of phenols or tar acids.

In addition to the various hydrocarbons, tar acids, and tar bases, smaller amounts of compounds containing sulphur have been found in coal tar. According to Lunge (10), the following sulphur compounds have been found in coal tar, and in all probability are present in the creosote oil: thioxene, trimethylthiophene, tetramethylthiophene, biophene, dithienyl, trithienyl, thionaphthene, thiophthene.

CHEMICAL PROPERTIES OF COAL-TAR CREOSOTES.

A comprehensive treatment of the chemical properties of the individual compounds found in creosote is outside the scope of this work, and reference is made for this information to the various textbooks on advanced organic chemistry. A few remarks, however, on the general reactions of creosote oil are desirable. In general, the reactions of the various reagents which may be applied to creosote oil are those expected of the aromatic hydrocarbons. Practically all of the hydrocarbons in coal-tar creosote have the capacity of forming beautifully crystallized addition compounds with picric acid. All the aromatic hydrocarbons are attacked by fuming sulphuric acid, and some of them by ordinary sulphuric acid with the consequent production of sulphonic acids, which are soluble in water. The tar acids are characterized by their solubility in caustic soda, in which they form sodium salts that are more soluble in water than in oil. The phenols themselves can be reprecipitated from the aqueous solution of the sodium salt by the addition of an acid, carbon dioxide being sufficiently strong to accomplish this result. The tar bases, as a rule, form addition products with the mineral acids at ordinary temperatures, and these addition products are soluble in water. These bases are also characterized in general by the formation of insoluble compounds with the noble metals and with mercury.

CHAPTER II. PHYSICAL PROPERTIES OF COAL-TAR CREOSOTES.

SOLUBILITY.

The solubility of creosote in some solvents may be considered as a physical property; in other solvents a chemical reaction is involved. Usually, coal-tar creosote is completely soluble in chloroform, carbon tetrachloride, carbon bisulphide, ether, and absolute alcohol, although the individual constituents that go to make up the creosotes are frequently not soluble in some of these solvents. The influence of soluble constituents in increasing the solubility of those that usually are not soluble in the oil is well known to chemists. As an instance of this, it may be cited that, in the purification of anthracene from a mixture of phenanthrene and anthracene, the original material is quite soluble in warm 95 per cent alcohol. On cooling, a considerable amount of very impure anthracene crystallizes. A greater amount of alcohol is now required to dissolve this anthracene than was required to dissolve the original material, although it has been reduced to a smaller amount. Each time the crystallization is effected, the material becomes somewhat purer, and finally the anthracene is scarcely soluble in absolute alcohol. All aromatic hydrocarbons are soluble in dimethyl sulphate, but the aliphatic hydrocarbons are not soluble in it. As a rule, therefore, coal-tar creosote is completely soluble in this reagent; but, if paraffin compounds are present, it can not be expected that they would be separated quantitatively by the use of this solvent alone.

COLOR AND ODOR.

The color of coal-tar creosote is usually a deep yellow to a dark brown, depending somewhat upon its age. When first distilled, it is a clear yellow oil with a greenish cast, which rapidly changes to brown on contact with the air. The odor is rather difficult to describe. If naphthalene is present in considerable quantities, this odor predominates, but in general the odor can be described only as "tarry."

FLASH AND BURNING POINTS.

It is usual in stating the physical properties of oils to give some idea of their flash and burning points. The composition of creosote oil varies so greatly, however, that the determination of the flash and burning points is of very little value. One might place the flash point at not less than 70° or 75° C., and the oil may be expected to flash at 80° C. under almost any conditions. The burning point is between 90° and 100° C.

VAPOR PRESSURE.

In the course of some experimental runs made by the Forest Service in a wood-preserving plant of light design, an explosion occurred which resulted in the rupture of the cylinder. It was thought at the time that, if the vapor pressure of the creosote oil were found to be sufficiently great, it might be an important factor in determining the design of treating plants. Experiments were therefore made to ascertain this vapor pressure at least approximately. Table 15 shows the average results obtained in experiments with two creosotes of different characteristics.

TABLE 15.—*Vapor pressure of coal-tar creosotes.*

Temperature (degrees C.).	Vapor pressure.		Temperature (degrees C.).	Vapor pressure.	
	Inches of mercury.	Pounds per sq. in.		Inches of mercury.	Pounds per sq. in.
50	2.0	1.0	110	7.4	3.7
60	2.8	1.4	120	8.2	4.1
70	3.6	1.8	130	9.0	4.5
80	4.6	2.3	140	9.8	4.9
90	5.6	2.8	150	10.6	5.3
100	6.4	3.2			

This vapor pressure is not sufficient to do any material harm, since it is always less than the atmospheric pressures at ordinary temperatures and elevations. If, however, the creosote contains water, the vapor pressure under this condition will be the sum of the vapor pressures of creosote and water. The vapor pressure of the mixture will be as shown in Table 16 if the vapor pressure of creosote, as given above, is used:

TABLE 16.—*Vapor pressure of mixtures of coal-tar creosote and water.*

Temperature (degrees C.).	Vapor pressure.		Temperature (degrees C.).	Vapor pressure.	
	Inches of mercury.	Pounds per sq. in.		Inches of mercury.	Pounds per sq. in.
40	3.0	1.5	80	18.6	9.3
50	3.5	2.7	90	26.2	13.1
60	8.6	4.3	100	36.4	18.2
70	12.8	6.4			

In this case, even at 100° C., the vapor pressure in excess of atmospheric pressure (15 pounds a square inch) is only 3.2 pounds a square inch, which is a pressure so small that it need not be taken into consideration in designing treating plants.

SPECIFIC HEAT.

It is frequently desirable to know the specific heat of creosote in order that allowance may be made for sufficient coils to heat the

tanks and cylinders in an economical manner. The average specific heat over a range from 15° to 90° C. has been roughly determined in the Forest Products Laboratory. The results given in Table 17 are not absolute specific-heat data, but include also the latent heat of fusion if the creosote is solid at room temperature. They are, therefore, somewhat greater than true specific-heat values. The specific heat of nine creosotes are shown in Table 17.

TABLE 17.—*Specific heat of coal-tar creosotes.*

Creosote No.	Specific heat.	Creosote No.	Specific heat.
614	0.337	679	0.373
636	.353	680	.349
638	.332	687	1.443
641	.323	740	.307
677	.339		

¹ This creosote contained large quantities of naphthalene. It was practically solid at room temperature. The figure is high because of latent heat of fusion.

The specific heat of creosotes may therefore be assumed to range between 0.30 and 0.45. If water is added, the mixture has a higher specific heat than creosote oil, and the rise in specific heat is in direct proportion to the amount of water present. Therefore, if treating plants are designed to handle aqueous solutions, ample provision will be made for the heating of creosotes.

SPECIFIC GRAVITY.

The specific gravity of a material is a physical property that is easily measured. Because of this fact, it is used to a large extent in industry to determine such factors as the strength of solution or the quality of oil.

The specific gravity of straight distilled coal-tar creosotes may vary from 1.01 to 1.08 or more. The usual temperature at which specific-gravity determinations are made is 38° C. and referred to water at 15° C. Practically the same result is obtained if the determination is made at 60° C. and referred to water at 60° C.

It is sometimes convenient to measure the specific gravity at some temperature other than the ones shown above. The change in specific gravity with change in temperature is 0.00077 per degree centigrade, or 0.00043 per degree Fahrenheit. This correction factor may be added to the determined value if the temperature is above the standard, or subtracted if it is below.

COEFFICIENT OF EXPANSION.

The factor usually termed the coefficient of expansion is the amount of change per unit volume if an oil is heated through 1 degree. This factor changes with the temperature and also with the different

gravities of oils, and at best the coefficient of expansion can be only a rough average of the various coefficients of expansion at different temperatures for different oils. In practice, it is usual to say that the change in volume is 1 per cent of the original volume for every 22.5° F. of temperature change. This factor is approximately accurate and is based on the fact that creosote oil changes its specific gravity roughly 0.0008 per degree centigrade, or 0.00044 per degree Fahrenheit. For commercial work over a short range of temperature, this factor is probably sufficiently accurate; but for refined work, such as the experimental determination of absorption of creosote by wood, the figure of the next decimal place should be known. Some work at the Forest Products Laboratory shows that the figure derived from the change of gravity per degree centigrade lies between 0.00077 and 0.00078, and between 0.000428 and 0.000433, with an average of 0.000430 per degree Fahrenheit. This work also shows that the actual change in gravity is independent of the initial gravity, provided the initial gravity at 10° C. is between 1.01 and 1.05; therefore a change in volume is dependent upon the initial gravity of the oil; that is, an oil with a specific gravity of 1.01, when heated through 100° F., will not have the same increase in volume as will an oil of 1.05 specific gravity heated through the same temperature difference. The volume, however, may be calculated by the use of the formula

$$V' = \frac{GV}{G - (T - T') 0.00077}$$

where T and T' are temperatures in degrees centigrade; or by the use of the formula

$$V' = \frac{GV}{G - (T - T') 0.00043}$$

where T and T' are the temperatures in degrees Fahrenheit. In these formulæ, V' is the volume at the temperature T' , V is the volume at temperature T , and G is the specific gravity at temperature T .

VISCOSITY.

Viscosity is a measure of the inner friction of liquids, that is, the friction produced by the liquid moving on itself. There are no instruments in commercial practice that measure this property directly. Most commercial viscosimeters are so constructed that the rate of flow of the liquid through an orifice of definite diameter under a definite head may be accurately measured. This does not give true viscosity, but does give an empirical measure of that property. Nearly all instruments are standardized by water at a fixed temperature. The efflux time in seconds of the liquid under examination divided by the efflux time of water at the standard temperature, is

sometimes known as "relative viscosity" or "specific viscosity," but more correctly as "Engler number" or "Saybolt number," as the case may be. Although there are a large number of viscosimeters on the market, no two makes will give exactly the same result because of the fact that these instruments work under a different head of liquid and have slightly different sizes of orifice. Results obtained by one make of instrument are, therefore, not directly comparable numerically with those obtained by another make. For that reason it is necessary to give the name of the instrument when viscosity readings are published. The instrument which seems to be

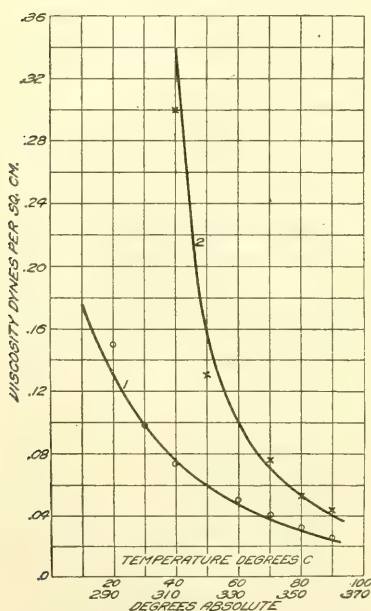


FIG. 28.—The change in viscosity of coal-tar distillates with change in temperature.

1. A high-boiling creosote.
2. A carbolineum.

in most general use in this country for measuring the viscosity of oils is that known as the Engler viscosimeter. The efflux time of water at 20° C., the standard temperature, is generally between 50 to 51 seconds. The Engler viscosimeter used at the Forest Products Laboratory has an efflux time of 50.8 seconds with water at 20° C. Tables have (15), however, been worked out by which results obtained in the Saybolt, Engler, and Redwood viscosimeters may now be converted to absolute viscosities, and hence from the readings of one instrument to those of another.

The viscosity of coal-tar creosote varies somewhat with the percentage of the higher-boiling constituents present. Those which have a large proportion of the higher-boiling oils are, of course, more viscous than those having a small percentage of

these oils. The extremes are represented by low-boiling creosotes on the one hand and by carbolineums on the other. The viscosities of creosote as well as of all other oils vary also with the temperature. In general, the higher the temperature the less the viscosity. This is not, however, a straight-line relation. Figure 28 shows the change in absolute viscosity with the change in temperature for an average coal-tar creosote and for a carbolineum.

The change in viscosity of creosote or carbolineums may be calculated from two or three determinations at different temperatures by the use of the formula $V = \frac{K}{T^A}$, where V is the absolute viscosity

in dynes per square centimeter, T the absolute temperature in degrees centigrade and K and A constants for the oil. When the viscosity is determined at the two temperatures, T_1 and T_2 , then

$$\frac{V_1}{V_2} = \frac{T_2^A}{T_1^A} \text{ or } \frac{\log V_1 - \log V_2}{\log T_2 - \log T_1} = A$$

substitute the value of A in the first equation and solve for K . The equation thus obtained will give the values of V at any temperature, providing the original determinations were accurate. The equations

for the two curves shown in figure 28 are $V = \frac{6.54(10)^{18}}{T^8}$ for the creosote and

$V = \frac{5.31(10)^{30}}{T^{12.63}}$ for the carbolineum.

The viscosity of oil is supposed to have an effect on its penetrance into wood, and it seems reasonable to suppose that a limpid fluid would be easier to inject than a more viscous one. Weiss (16) stated that penetrance is some inverse function of the viscosity. Bond (17) showed that, in the different mixtures of creosote and carbon-free tars tested, there was no apparent relation between the viscosities of the creosotes and the penetration obtained. He also showed that the same thing was true when mixtures of normal tar and creosote were used.

Later, Teesdale and MacLean (18) stated that there was no apparent relation between the viscosity and the penetrance of the tar mixtures used. Their statements are, however, based on the viscosity as determined by the Engler viscosimeter. Since then their data have been recalculated to absolute viscosity and show that a very definite relation exists between absolute viscosity and penetrance, and that this relationship is capable of mathematical treatment. However, the data are not as yet sufficiently extensive to show the relationship of other variables which enter into the penetrance.

Figures 29 and 30 show the relationship between longitudinal penetration and absolute viscosity of various oils, including creosote oils, tar mixtures, tars, and asphaltic oils into noble fir and long-leaf pine. The equations given in the figures are of value only when the other conditions used in the test are held constant. Other factors which may influence the penetration are the time of treatment, the pressure used, and the moisture content in the wood. In all probability a full equation should read $M, P, T, XY = K_2$, where M is some function of the moisture content, P some function of the pressure used in treatment, T some function of the time of pressure, Y the absolute viscosity, X the longitudinal penetration, and K_2 a constant. In these experiments the moisture content, pressure of treat-

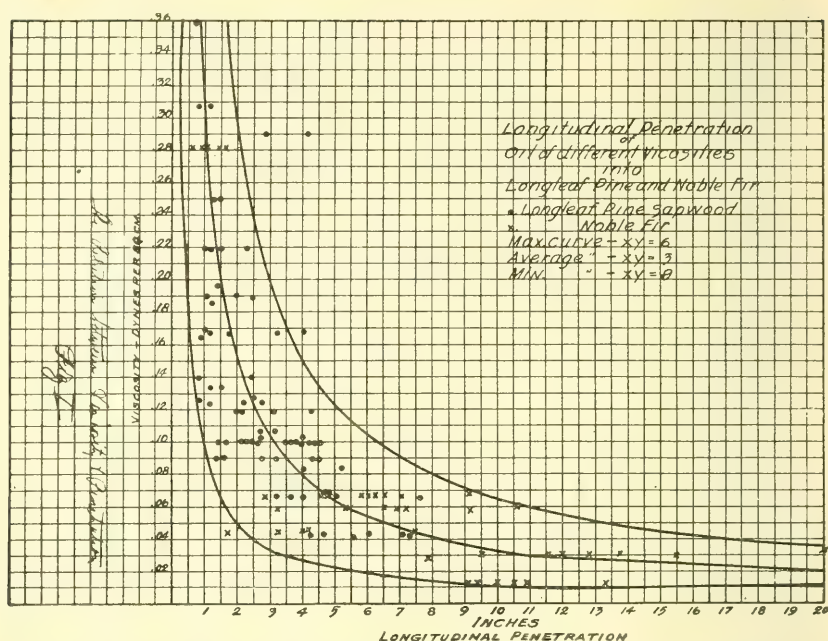


FIG. 29.—Longitudinal penetration of oil of different viscosities into longleaf pine and noble fir.

°—Longleaf pine sapwood.
*—Noble fir.

Max. curve— $xy=6$.
Average curve— $xy=3$.
Min. curve— $xy=0$.

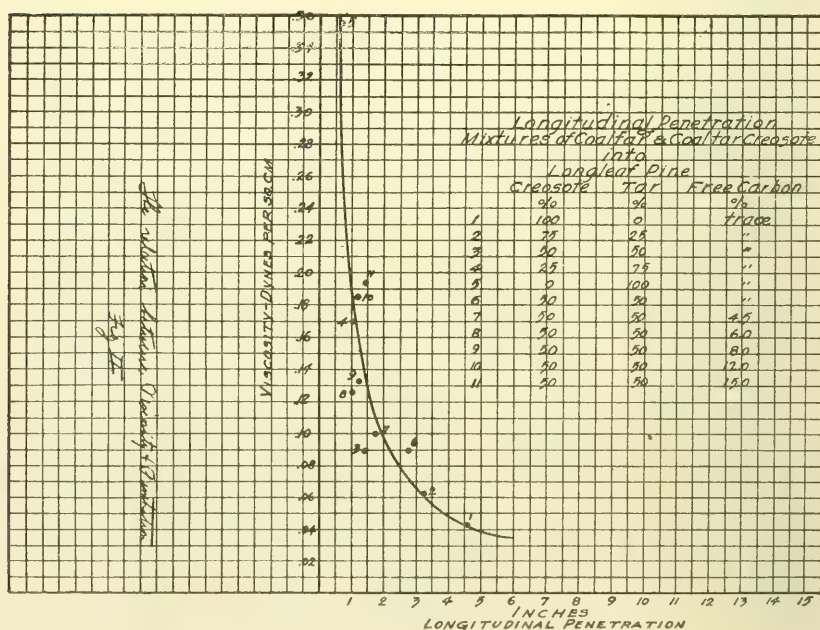


FIG. 30.—Longitudinal penetration. Mixtures of coal tar and coal tar creosote into longleaf pine.

ment, and time of treatment were held constant. The equation is simplified by dividing through by these numbers, but it must not be lost sight of that they belong in the equation, and that the equation $XY = K$ holds only when M , P , and T are constant.

VOLATILITY.

There is, perhaps, no physical property of coal-tar creosote that is of greater interest to the wood-preserving industry as a whole than its volatility, because the permanence of the treatment is largely dependent upon the volatility of the creosote. Alleman (19), Von Schrenk (20), Bateman (21), Ridgway (22), Rhodes and Hosford (23), and Mattos (57) in this country have shown that the oils present in piling, ties, and poles, after long use, have contained large amounts of the higher-boiling fractions of creosote. The loss was restricted chiefly to that portion of the creosote which distilled below 245° C., although there was also an appreciable loss in the portion distilling between 245° C. and 270° C. Above 270° C., however, the oil seemed to be fairly permanent. It has been shown by the Forest Products Laboratory that, if the assumption is made that there is no loss above 270° C., then the loss by evaporation may be calculated from an analysis of the original creosote and of the creosote extracted from wood that had been in service a long time. The correctness of this assumption is shown by the fact that calculations made from analyses of oil before and after use in open-tank treatment showed a loss of 41 per cent. A record of the amount of creosote in the timber after treatment and the amount used during treatment showed that there had been at least 38 per cent of loss, or practically the same figure as calculated from the analyses.

Instead of the residue about 270° C., some investigators had used the pitch residue, that is, the residue above 315° C. Although it is probable that, if the oils boiling above 270° C. are practically nonvolatile, then the pitch residues should possess this property to an even greater degree, yet, on account of the size of the fraction, calculations based on the pitch residue are more liable to error than those based on the residue above 270° C. This is because there is about the same accuracy in determining the pitch residue by weight as there is in determining the residue above 270° C. As the latter fraction is usually two and sometimes three or four times as great as the former, an error in determining the residue above 270° C. is only half as great on a percentage basis as would be the same error in determining the amount of pitch. This is shown very well by the following calculations. Creosote was allowed to evaporate in a pan and its loss was accurately determined. The analysis of this creosote before and after evaporation is given in Table 18.

TABLE 18.—*Distillation of oil before and after evaporation.*

Temperature (degrees C.).	Creosote before evapo- ration.	Creosote after evapo- ration.
	<i>Per cent.</i>	<i>Per cent.</i>
Up to 210...	2.2	0.2
210 to 235...	23.3	0.8
235 to 270...	24.1	14.1
270 to 315...	17.5	32.0
315 to 355...	17.1	27.3
Residue....	17.5	25.6

The actual loss produced by evaporation was 41.5 per cent. The loss calculated from the pitch residue was 43.2 per cent. The loss calculated from the residue above 270° C. was 41.1 per cent. By the pitch-residue method, the maximum difference is 1.7 per cent, and the maximum difference by residue above 270° C. is 0.4 per cent. As the data used in both cases were the same, these differences are due to the method of calculation rather than to any error in analysis.

In most cases it is impossible to obtain records of any kind that will show the composition of the creosote used in the treatment of old timbers. Two such records are furnished by the pole lines of the American Telephone & Telegraph Co. This company has a number of analyses of the original oils used, from which a fair average may be obtained. One line, the Washington-Norfolk line, was erected in 1897; the other, the Montgomery-New Orleans line, was erected in 1899. Five poles in the Washington-Norfolk line were removed in 1906 and one in 1908 for analysis. One pole from the Montgomery-New Orleans line was removed in 1908 for analysis.

The analysis of the creosote before treatment was obtained from the American Telephone & Telegraph Co., which makes the following report:

The original reports of the analysis are in our files and from which we have prepared the following table as indicating the average of the oil used in the treatment of the poles for that line. It is, of course, impossible to associate the poles under test with any particular analysis of oil.

TABLE 19.—*Average of tests of dead oil of coal tar used in treating poles.*

DISTILLATES.	Per cent.
Loss, water, etc., 170° C.....	1
170° to 205°.....	2
205° to 210°.....	4
210° to 235°.....	45
235° to 240°.....	7
240° to 270°.....	16
270° to 316°.....	9
Residue above 316°.....	16

Twenty-eight analyses were available for the above average.

For the distillate between 205° and 235° C.,

	Per cent.
19 analyses averaged about.....	45
3 analyses averaged between.....	50 and 55
2 analyses averaged between.....	55 and 60
4 analyses averaged between.....	60 and 65

The analyses of the creosotes extracted from five of the poles from the Washington-Norfolk line were published by Von Schrenk, Fulks, and Krammerer (20). Later, Rhodes and Hosford (23) published independent analyses of the creosotes from the same poles and, in addition, of one other creosote from the same line and of one from the Montgomery-New Orleans line. The records of both series of investigations are given in table 20.

TABLE 20.—Analyses of creosotes extracted from telephone poles.

Pole No. and fraction.	Top.		Butt.	
	V. S., F., and K., per cent.	Rhodes and Hosford, per cent.	V. S., F., and K., per cent.	Rhodes and Hosford, per cent.
Pole No. 10749.				
Below 210° C.....	0.0	1.8	0.0	2.3
210° to 235° C.....	6.7	6.5	37.4	42.5
235° to 270° C.....	31.0	23.9	26.9	22.5
270° to 315° C.....	21.3		14.2	
Residue.....	41.0	67.8	20.4	32.7
Pole No. 1425.				
Below 210° C.....	8.6	7.9	0.0	1.9
210° to 235° C.....	29.7	32.0	45.0	39.6
235° to 270° C.....		19.4	23.0	23.7
270° to 315° C.....	32.1		11.3	
Residue.....	29.6	40.7	16.1	34.8
Pole No. 9709.				
Below 210° C.....	0.0	3.1	0.0	2.4
210° to 235° C.....	1.0	6.7	12.9	15.6
235° to 270° C.....	8.2	18.2	25.7	24.8
270° to 315° C.....	32.2		18.9	
Residue.....	58.6	71.9	42.5	57.2
Pole No. 29.				
Below 210° C.....	0.0	3.2	1.0	0.5
210° to 235° C.....	40.7	21.4	47.1	44.3
235° to 270° C.....	19.0	24.2	19.2	25.7
270° to 315° C.....	11.5		12.9	
Residue.....	28.8	51.2	19.4	29.5
Pole No. 2931.				
Below 210° C.....	0.0	1.7	0.0	2.3
210° to 235° C.....	31.7	22.4	40.6	35.8
235° to 270° C.....	20.4	14.1	22.3	16.4
270° to 315° C.....	7.7		12.0	
Residue.....	39.9	61.8	24.7	45.5

Fraction.	Rhodes and Hosford, pole 5348.			Rhodes and Hosford, pole 10272.		
	Top.	Above ground line, per cent.	Below ground line, per cent.	Top.	Above ground line, per cent.	Below ground line, per cent.
Below 210° C.....	1.9	1.2	2.1	0.6	0.3	4.0
210° to 235° C.....	4.0	4.4	14.4	.7	.7	9.4
235° to 270° C.....	6.6	21.5	29.9	2.9	3.1	21.6
Residue.....	87.5	72.9	54.6	95.8	95.9	65.0

Messrs. Von Schrenk, Fulks, and Kammerer, using the pitch residue of the average creosote before treatment and the pitch residue of the individual creosotes after treatment, estimate the loss by volatilization to be as shown in Table 21.

TABLE 21.—*Loss of creosote by volatilization from telegraph poles.*

Pole No.	Section of pole.	Loss, per cent.	Pole No.	Section of pole.	Loss, per cent.
10,749	Top.	59.0	1,425	Butt.	2.7
10,749	Butt.	20.8	2,931	Top.	58.0
29	Top.	42.4	2,931	Butt.	32.8
29	Butt.	16.4	9,709	Top.	70.8
1,425	Top.	43.3	9,709	Butt.	60.3

The same investigators analyzed the oils extracted from the north and south sides of two poles; but, on account of lack of concordance in results, they could not state definitely whether there was any difference in evaporation corresponding to the difference in these two points of the compass. They also made a few analyses to determine the difference in evaporation near the surface and in the interior of the treated portions. Their results show a slight but gradual increase in the volatility of the creosote extracted from the center over that obtained from the outer portions; but the investigators state that more analyses should be made.

Even an average analysis of the creosote is not usually available. If, therefore, it is desired to determine the loss by volatilization, another assumption must be made. Much of the treated wood examined after long service is piling. In a pile there are three different parts that represent three different conditions of exposure—first, that part of the pile exposed to the air, or the air section; second, that part of the pile that is in the water, or the water section; and, third, the point of the pile, which is in the mud, or the mud section. The mud section is less likely to change than either of the other two, since the loss by evaporation and the loss by solution are both nearly negligible. The assumption that there is no appreciable loss of the creosote in the point seems, therefore, to be justifiable; at any rate, the figures obtained by using this assumption would be less instead of greater than the actual loss, even if the assumption is liable to be considerably in error. Basing calculations on these two assumptions, namely, that the fractions above 270° C. do not disappear appreciably, and that the creosote in the point is the same as the original creosote, the calculations shown in Tables 22 and 23 have been made to show the losses occurring from piling that has been in service for different lengths of time under different conditions.

TABLE 22.—Analyses and calculated losses of creosote from treated piling.

Length of service, years.	Character of oils.						Loss.				Observer.
	In point.		Below water line.		Above water line.		Below water line.		Above water line.		
	Up to 245° C.	Up to 270° C.	Up to 245° C.	Up to 270° C.	Up to 245° C.	Up to 270° C.	Total.	Average.	Total.	Average.	
	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	<i>P. ct.</i>	
38.	37. 8	52. 2	23. 3	41. 9	20. 4	31. 7	17. 0	0. 42	30. 0	0. 79	Ridgway (22).
38.	39. 5	51. 9			16. 8	29. 8			31. 4	. 83	Do.
20.	59. 9	69. 6	59. 8	69. 3	57. 7	65. 9	1. 0	. 05	11. 0	. 54	Do.
20.	61. 1	70. 9	52. 7	63. 5	48. 4	58. 5	20. 0	1. 0	30. 0	1. 5	Do.
20.	60. 4	68. 5	49. 9	58. 7			23. 7	1. 2			Do.
30.	41. 8	48. 2	33. 3	40. 4	10. 2	30. 5	13. 0	. 4	26. 0	. 8	Bateman (21).
30.	9. 4	21. 5		4. 6	5. 8	11. 6	17. 7	. 6	10. 0	. 3	Do.
	Up to 235° C.	Up to 270° C.	Up to 235° C.	Up to 270° C.	Up to 235° C.	Up to 270° C.					
29.	42. 0	53. 2	54. 0	73. 4	33. 3	58. 9					Mattos (57).
29.	7. 6	32. 3	4. 1	20. 5	5. 2	20. 5					Do.
22.	6. 9	28. 6	1. 8	24. 0		14. 9					Do.
20.	16. 1	38. 5	4. 1	28. 8	1. 2	9. 2					Do.
18.	11. 5	41. 6	15. 2	46. 1	15. 4	40. 1					Do.

TABLE 23.—Analyses of creosotes extracted from old timbers after various lengths of service.

Sample.	Service.	Creosote per cubic foot.	Distillation of extracted oil.							Total.	Tar acids.
			To 205°.	205° to 245°.	245° to 270°.	270° to 320°.	320° to 420°.	Residue above 420°.			
	<i>Yrs.</i>	<i>Lbs.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>		<i>Cm(3).</i>
Tie No. 106.....	16	4.06	.....	16.32	13.24	20.15	24.10	25.93	99.74	.....	0.51
Tie No. 104.....	18	9.24	.....	9.37	18.17	27.54	21.38	23.01	99.47	.....	.36
Tie No. 113.....	18	8.01	.....	9.75	18.54	24.96	22.42	24.07	99.74	.....	1.13
Tie No. 109.....	16	8.29	.....	7.08	12.45	16.68	40.84	22.52	99.57	.....	.74
Pile No. 118.....	47	7.68	.....	19.92	17.58	20.62	14.48	27.11	99.71	.....	.78
Tie No. 107.....	42	12.71	.....	9.45	12.30	27.56	33.48	17.87	100.66	.....	.96
Tie No. 105.....	1 ³ 33	5.08	.....	6.83	10.16	26.11	32.17	23.91	99.18	.....	.....
Tie No. 103.....	19	14.07	.....	17.78	11.88	21.26	14.64	34.01	99.57	.....	.26
Tie No. 110.....	19	13.84	.....	18.23	16.61	23.01	12.78	29.11	99.74	.....	.68
Paving blocks Nos. 88 and 89.....	20	17.19	.....	20.13	10.27	12.18	27.46	29.78	99.82	.....	1.19
Tie No. 114.....	30	7.41	.....	15.44	7.44	15.68	44.96	16.14	99.66	.....	.37
Paving blocks Nos. 90 and 91.....	11	14.37	.....	21.03	24.45	7.68	25.06	21.78	100.00	.....	.87
Tie No. 108.....	23	5.17	.....	10.59	12.61	28.56	20.32	27.87	99.95	.....	.62
Tie No. 2.....	20	5.93	.....	15.78	8.04	27.80	18.12	29.81	99.55	.....	.76
Tie No. 3.....	20	9.03	.....	10.15	16.32	20.54	12.63	40.02	99.66	.....	.54
Tie No. 41.....	22	12.76	.....	10.46	20.34	22.63	16.32	29.83	99.58	.....	1.14
Tie No. 101.....	24	11.46	.....	8.32	26.36	23.42	29.58	11.86	99.54	.....	.38
Tie No. 102.....	21	8.19	.....	18.24	12.16	28.92	22.76	17.35	99.43	.....	.21
Tie No. 112.....	14	7.21	0.47	7.65	8.03	17.58	38.88	27.97	100.58	.....	1.23
Pile No. 116.....	46	8.42	.....	9.44	16.92	29.68	32.08	11.03	99.15	.....	.....
Pile No. 111.....	46	8.07	2.76	19.53	14.61	18.15	17.23	27.03	99.31	.....	.....
Pile No. 117.....	46	9.31	.....	22.20	20.10	24.30	16.24	16.84	99.68	.....	.....
Pile No. 4.....	46	12.61	.....	16.87	12.15	13.25	25.37	32.30	99.94	.....	1.07
Pile No. 5.....	21	9.06	.....	13.56	10.52	20.34	31.24	23.92	99.58	.....	1.78
Tie No. 8.....	22	12.36	.....	9.03	15.21	29.45	13.35	32.91	99.96	.....	1.37
Tie No. 9.....	16	9.42	.....	6.39	10.38	27.75	31.86	23.51	99.89	.....	1.15
Pile No. 81.....	11	18.34	.....	38.88	13.76	13.12	10.08	24.02	99.86	.....	.....
Pile No. 82.....	15	19.12	.....	51.50	12.35	3.74	11.61	21.03	100.23	.....	.....
Pile No. 83 ²	7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Pile No. 84.....	20	8.43	.....	13.56	15.78	14.49	19.77	36.13	99.83	.....	.....
Pile No. 85.....	17	13.21	.....	19.07	12.39	12.32	17.58	38.14	99.50	.....	.....
Tie No. 86.....	22	¹ 19.36 ⁴ 16.14	.....	22.53	13.47	22.63	18.58	22.37	99.58	.....	.....
Pile No. 50.....	29	17.63	1.26	27.60	22.43	31.22	12.02	5.13	99.66	.....	.....
Pile No. 51.....	29	17.08	2.18	31.06	18.21	36.04	8.17	4.13	99.79	.....	.....
Paving block No. 52.....	34	18.81	.48	26.61	32.06	17.52	8.47	14.42	99.56	.....	.....
Paving block No. 53.....	29	12.44	.68	17.57	18.78	37.52	16.62	8.56	99.73	.....	.....
Paving blocks Nos. 54 and 55.....	29	⁶ 6.07 ⁵ 5.46	9.62	14.41	19.27	41.74	11.23	3.40	99.67	.....	.....
Conduit pipe No. 67.....	14	8.74	5.08	27.23	10.46	27.68	19.03	9.93	99.41	.....	.....

¹ Twenty years as a tie and 13 years as a fence post.² Treated with creosote and resin. Not analyzed.³ Center.⁴ Under rail.⁵ Paving block No. 54.⁶ Paving block No. 55.

From a comparison of Table 21 with Table 22 it will be seen that the loss from piling is much less than the loss from poles, although in some of the piling there was a greater percentage of creosote distilling below 245° than there was in the poles, the loss from the butt in the poles being on an average somewhat greater than the loss from the air section in the piles, and considerably greater when it is considered on an average yearly basis. Table 23 shows the analyses of creosote extracted from woods that have been subjected to different lengths of service. No estimate of the loss on this material can be made, but attention is called to the fact that, in spite of the very heavy loss that was probably experienced (see Tables 21 and 22), the fractions distilling below 245° have not disappeared entirely. These fractions are the ones that usually contain the tar acids and the tar bases, both of which are known to be very toxic. Not all the investigators made determinations for tar acids, but in 65 per cent of the analyses that were made the acids were found. The absence of tar acids does not necessarily indicate that these compounds have volatilized, because it is possible for them to undergo chemical changes, as pointed out by S. Cabot (24), or for them to attack the cellulose or wood substance in such a way as to produce materials resembling bakelite, or for them to be dissolved in the water contained in the wood, and a part of them at least to penetrate into the apparently untreated portion of the wood. In any one of these conditions the tar acids would probably be missed by the investigator.

No short test is known to the writer that will give the volatility of creosote in any but a comparative way. For this purpose an examination of the percentage of distillate would probably serve as well as any other test. A number of tests have, however, been made both by evaporation from open dishes or pans and by evaporation from the treated wood. Figure 31A shows the loss of creosote by evaporation from open pans or dishes under two conditions of heating, and the percentage distilling at 270° C. The points fall roughly in a straight line. Figure 31B shows the same kind of relation between the amount distilling at 270° C. and the loss from creosoted wood. The relation here is represented by a nearly straight line, but the slope is much steeper than before. Furthermore, the maximum loss is less than half that in the dish test, although the oils were much lighter in character.

Von Schrenk and Kammerer (25) have reported a number of tests on six creosotes under three sets of conditions; that is, evaporation from open pans at room temperature for 304 days, evaporation for the same length of time from maple blocks, and evaporation from pine blocks. Using this length of time, the investigator shows that the loss by evaporation from the open pan is practically the same as the loss by evaporation from wood under the same conditions for

the creosotes tested. Beyond the time of 304 days the blocks gained in weight, probably because of the absorption of moisture. The results of these tests are plotted in figure 31c, in which the ordinates are the percentages distilling at 270° C. and the abscissæ are

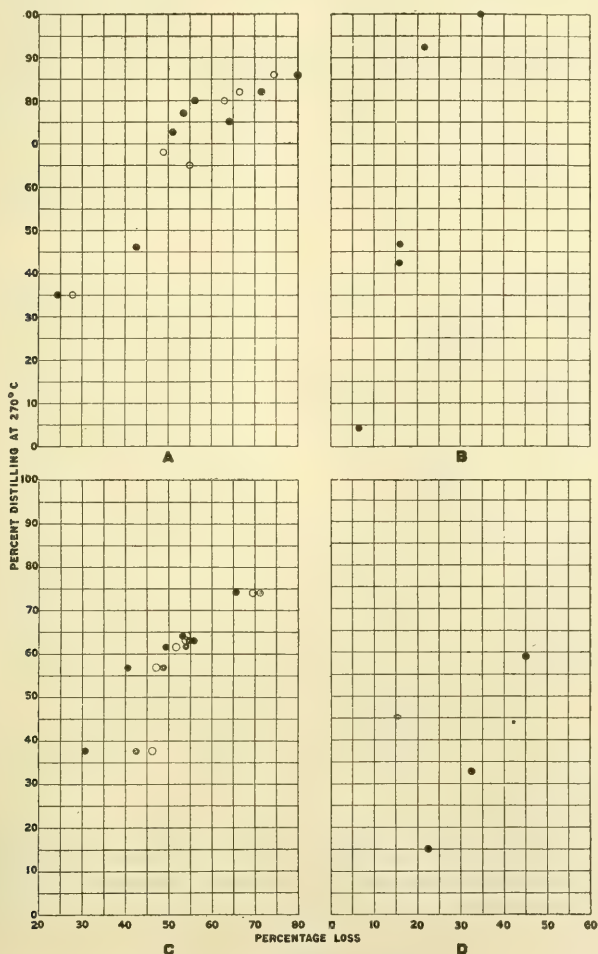


FIG. 31.—Relation between the loss by evaporation and the per cent of the oil volatile below 270° C.

- A. Loss of coal-tar creosote by evaporation from open pans.
- B. Loss of coal-tar creosote by evaporation from creosoted wood.
- C. Loss of coal-tar creosote by evaporation from pans and creosoted wood. Dots—Open pans. Circles—Maple blocks. Double circles—Pine blocks.
- D. Loss of water-gas tar creosote by evaporation from open pans.

the percentages of loss by evaporation. The three points lying in the lines parallel to the abscissæ are obtained by using the same creosote in the three different methods of test.

Recently Bateman and Town (26) have shown that the loss of creosote by weight because of evaporation in laboratory open-tank treatments is in direct proportion to the area of the surface of the oil, and is also dependent upon the volatility of the creosote. They give the equation $\log L = 0.0165 V - 0.347$ as the daily loss per square foot of exposed surface, when the temperature of the bath is 195° F. In this equation $\log L$ is the logarithm of the loss and V is the percentage of creosote distilling below 270° C. The constants 0.0165 and 0.347 will vary if any of the conditions are used except those under which the experiment was carried out. Figure 32 gives a curve of the above equation, with the experimental data plotted upon it.

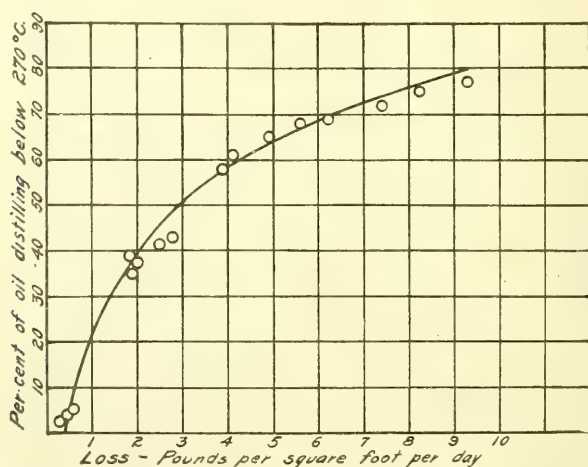


FIG. 32.—Relation between the volatility and the loss by evaporation of creosotes from open tanks.

Calculations show that it is very likely there is a mathematical relation between the rate of loss of creosote from treated wood and the amount and character of the creosote injected. The general form of the equation, as obtained from preliminary calculations, is

$$\frac{KA^2(1-Y)^3Y^2}{B-Y} = X$$

where K is a constant for the location, A is the weight of creosote injected per cubic foot of wood, B the percentage of creosote distilling below 270° C., Y the loss by evaporation, and X the time required.

Figure 33 gives two curves in which the above equation has been used on two different creosoted sticks which had different grades of creosotes and different absorptions per cubic foot. In one curve the amount of oil distilling below 270° C. was 92 per cent, in the other curve 49 per cent. The amounts of oil injected per cubic foot were

f K in
s are

which
on the

than it
tion of
of ties
y light
d itself
and 25
wn and

TABLE 24.—Service records of creosoted ties treated by pressure treatments from 1872 to 1903.

Date placed	Number in test.	Species.	Railroad.	Location.	Treatment.	Results of inspection.				Cause of removal.	Data obtained from.	Analyses of creosote used.						Remarks.	
						Date.	Service.	Removals.	Average life.			Specific gravity.	Up to 210° C.	Up to 235° C.	Up to 260° C.	Up to 315° C.	Up to 335° C.		Tar acids.
						Years.	Per cent.	Years.			Per cent.	Per cent.	Per cent.	Per cent.	Per cent.				
1872	5,000	Hemlock.	C. R. I. & P.	Chicago, Ill.		1882	10	50-70		Rail-cut and decay.									
1876	5,000	Cedar.	C. R. R. of N. J.	Round Brook, N. J.		1885	19	100		do.									
1876	100	do.	H. & T. Co.	Midway, Mass.		1887	20	20		do.									
1878	15,000	do.	L. & N.	Texas.		1896	18	40-55		Flood 1886; records lost.									
1879	1,883	do.	do.	do.		1903	20		15.5	Rail-cut and spike-killed.									
1879	5,000	Shortest pine.	C. R. R. of N. J.	do.		1903	24			Some reason for believing few ties still in service in 1916.									
1880	150,000	Pine.	H. & T. Co.	Midway, Mass.		1906	25	92.5	19.0		Spec.	About 1.05		60	75		5		
1880	400	Hemlock.	N. Y. N. H. & H.	do.				30.0		Rail-cut; not rotten; one tie in use as fence post in 1912.									
1884		Yellow pine.	Grand Central Yards.	New York City.		1900	16			Relaid, 1900.									
1884		Oak and pine.	H. & T. Co.	do.		1906	22												
1887	232	Longleaf pine.	A. C. L.	Halifax, N. C.	Rueping.	1916	29	99		Rail-cut and decay; remaining ties badly rail-cut but sound.									
1888		Hemlock.	N. Y. N. H. & H.	Somerset, Mass.		1911			20.0										
1891-2	5,500	Mixed.	N. J. C.	Highlands Pier.		1907				Most removed 1897, balance 1910.									
1891-2	6,000	Pine.	N. Y. N. H. & H.	Fairhaven tunnel.		1916	22	99.6		25 ties still sound.									
1896	76,100	Various.	N. I. C.	Central division.		1909	13	32		Rail-cut.									
1897	25	Juniper.	N. & S.	Norfolk division.		1917	30	76	17.0	Start to fail in 1909.	Spec.	N. L. T. 1.03	N. L. T. 50 per cent naphthalene.	N. L. T. 20 per cent anthracene.					
1897	75	do.	do.	do.		1917	30	51		Start to fail in 1911.									
1901	190	Sawed s. y. pine.	A. T. & S. F.	Ponca, Okla.	Rueping.	1917	13	4.7		1.5 per cent decay; 3.2 wear.									
1901	272	Hewed s. y. pine.	do.	Bliss, Okla.	do.	1917	13	4.7			Anal.		14.9	164.3					
1901	362	Sawed s. y. pine.	do.	Parry, Okla.	do.	1917	13												
1901	27	Hewed s. y. pine.	do.	do.	do.	1917	13												
1903	304	do.	do.	do.	do.	1917	12	43.8		2.6 per cent decay; 10.9 wear; 30.3 switch ties.	Spec.	1.04 to 1.10	N. M. T. 5	N. M. T. 30					
1903	572	Sawed s. y. pine.	do.	Argonia, Kans.	do.	1917	12	42.3		4.2 per cent decay; 33.5 wear.									
1903	44	Hewed s. y. pine.	do.	Sutton, Kans.	do.	1917	12	11.4		Wear.									
1903	84	Sawed s. y. pine.	do.	Garnet, Kans.	do.	1917	12	18.7		15.1 per cent decay; 5.6 wear.									
1905	33	Sawed red gum.	G. H. & S. A.	do.	do.	1917		31.8											
1905	29	do.	do.	do.	do.	1917		17.2											
1905	45	do.	do.	do.	do.	1917		72.1											
1905	39	do.	do.	do.	do.	1917		38.3											
1905	38	do.	do.	do.	do.	1917		47.8											
1905	33	Sawed tupelo gum.	do.	do.	do.	1917		16.7											
1905	23	do.	do.	do.	do.	1917		20.0											
1905	44	do.	do.	do.	do.	1917		55.7											
1905	36	do.	do.	do.	do.	1917		36.2											
1905	33	do.	do.	do.	do.	1917		31.2											
1905	83	Red oak.	St. L. & S. F.	Paup, Mo.	do.	1917	12	13.3			Anal.	1.09	2.9	10.6		62.73	68.0		
1906	40	do.	do.	do.	do.	1917	12	10.0											
1906	752	do.	do.	do.	do.	1917	11	19.5		8.4 per cent decay; 11.1 wear.									
1906	221	do.	do.	do.	do.	1917	11	14.3		7.8 per cent decay; 6.5 wear.									
1906	205	Pine.	G. H. & S. A.	Salix, La.	Full cell.	1917	11	22.0											
1906	285	do.	do.	Lafayette and Scott.	do.	1917	11	68.7											
1906	560	do.	N. Y. N. H. & H.	Fairhaven tunnel.	do.	1916	10												
1906	24,228	do.	A. T. & S. F.	Ottawa cut-off.	Rueping.	1917	11	1		Wear.	Spec.	No record.	1.04 to 1.10	N. M. T. 5	N. M. T. 30				
1907	390	Red gum.	do.	Hutchinson, Kans.	do.	1917	10	2.8		1.3 per cent decay; 1.5 wear.									
1907	230	do.	do.	do.	do.	1917	10												
1907	362	do.	do.	do.	do.	1917	10												
1907	1,000	Libberty pine.	G. R. R.	Union Point, Ga.	Full cell.	1916	9	3.3		1.5 per cent wear.	Spec.	1.04 to 1.10	N. M. T. 5	N. M. T. 30					
1907	1,000	do.	do.	do.	do.	1916	9	2.3		Decay.		No record.							
1907	2,491	do.	C. B. & Q.	Sheridan, Wyo.	do.	1916	9	36.0		Checked.	Anal.	1.076	11.4	31.7	57.7				
1907	3,300	Shortest pine.	N. Y. N. H. & H.	East of Greenwich.	Rueping.	1919	10	65.0		Wear.									
1907	390	N. y. pine.	do.	Fairhaven tunnel.	Full cell.	1916	9	22.0											
1907	1,274	do.	do.	do.	do.	1916	9												
1908	46	Red oak.	M. P. N.	Faulk, Ark.	do.	1917	10	2		Broken.	Anal.	1.024	7.5	45.0	250° C. 75.0				
1908	95	do.	do.	do.	do.	1917	9	2			Spec.		5.0	40.0	80.0				
1908	95	do.	C. B. & Q.	Lines east.	Full cell.	1917	9	1.0		Split.	Anal.	1.076	11.4	31.7	57.7				

N. L. T. = Not less than.

N. M. T. = Not more than.

Up to 210° C.

Up to 230° C.

TABLE 25.—Service records of creosoted telephone poles treated by pressure treatments.

Date placed.	Number placed.	Location.	Species.	Date inspected.	Service.	Number of poles inspected.	Decayed to point of reconstruction.	Total poles showing decay.	Average of—	Analysis of oil used.				
										Specific gravity.	Distillation.			
											Up to—			
											210° C.	235° C.	270° C.	315° C.
1897	9,975	Washington-Norfolk line.	Yellow pine.	1914	17	1,690	2.7	8.7	28 analysis.	1.022	Per cent.	Per cent.	Per cent.	Per cent.
1899	7,645	Montgomery-New Orleans.	do.	1915	10	1,538	5.3	32.4	38 analysis.	1.03	7	50	75	84

75330*—22. (Page p. 65.)

10.48 pounds and 18.79 pounds, respectively. The value of K in these experiments was $\frac{3.3}{100}$. The equations for the two curves are

$$\frac{3.74(1-Y)^3 - Y^2}{92-Y} = X, \text{ and } \frac{11.68(1-Y)^3 - Y^2}{49-Y} = X,$$

respectively. The curves and data are plotted independently.

It would appear, however, notwithstanding the great loss which must certainly have occurred, that the effect of this loss upon the

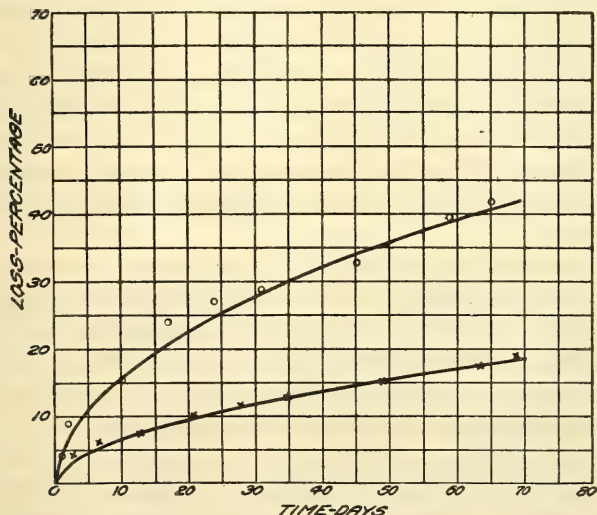


FIG. 33.—The relation between the volatility and loss by evaporation of creosotes from treated wood with time.

life of the treated timber may have been given more weight than it really deserved, particularly as to its effect upon the prevention of decay. Bateman (27) has shown that in all service records of ties and telephone poles, many of which were treated with very light creosote, the failures are due to mechanical failure of the wood itself and not to the failure of the creosote to protect. Tables 24 and 25 show the service records from which these conclusions are drawn and the analyses of the oils used.

CHAPTER III. TOXIC PROPERTIES OF COAL-TAR CREOSOTES.

To be an efficient wood preservative, any oil must have at least two properties: It must be toxic; that is, able to destroy or to inhibit the growth of the organisms that cause the destruction of timber, and it must be as nearly permanent as possible. In addition to these two, it may have other properties, such, for example, as that of waterproofing, which would aid in the retardation of fungous growth. The most efficient wood-preserving oils, therefore, must possess a high degree of toxicity combined with a high degree of permanence. The long service of timbers treated with coal-tar creosote shows conclusively that coal-tar creosote possesses these properties to a marked degree.

Toxicity tests may be divided into three groups or classes: (1) tests on timber-destroying fungi; (2) tests on marine borers; and (3) tests on insect borers. The first two are of the greatest importance to the wood-preserving industry at the present time. The tests on fungi may be conducted in at least three ways: (1) by Petri-dish tests, which require only a short time for their completion; (2) by fungus-pit tests, requiring a somewhat longer time; and (3) by service tests, requiring from 4 to 10 years to obtain the results. The last is, of course, the most conclusive proof of the preserving value of any wood-preserving oil, but requires an exceedingly long time, and is, moreover, a test that combines permanence and toxicity. Furthermore, in such tests not infrequently the wood fails mechanically before the usefulness of the preservative is ended. The first and second are only comparative tests and show what might be expected of any wood preservative when compared with some other material of known value. In these two tests the factor of permanence is largely but not completely eliminated; it is, therefore, possible that a material which under tests promises to be a very effective preservative may not prove to give good service because of its lack of permanence.

FUNGUS-PIT TESTS.

Fungus-pit tests have been started by the Forest Products Laboratory, by Chapman (28), of Westinghouse, Church, Kerr & Co., and by Hosford, of the American Telephone & Telegraph Co., and probably by others. At the Forest Products Laboratory the tests consisted of placing blocks treated with various preservatives in a concrete pit in which the humidity and temperature could be

controlled, and of inoculating these blocks with timber-destroying fungi. The test at the laboratory has not been successful in destroying the treated wood. In the light of present knowledge only negative results could be expected from such tests.

Chapman (28) brush-treated his test specimens and set them in sheep manure. Experiments with brush-treated fence posts and telephone poles show that such a test will not be a test of the preservative, but that the wood will decay because checks and cracks develop and permit the entrance of fungi into the untreated section long before the treated portion has lost its resistance to decay. The original conception of the fungus-pit test was that the life of a preservative could be determined in a shorter time than by service tests, but the tests so far carried out have failed to obtain this result. The reason has been either that specimens which have decayed were not treated in such a manner as to give the preservative life of the creosote; or that the conditions in the fungus-pit were such that the creosote did not lose its vitality as it does under exposure.

PETRI-DISH TESTS.

There are various ways of making Petri-dish tests, which vary with different operators. Objections or criticisms can probably be brought against any one of the systems now in use. The general principles of the tests, however, are the same. A nutrient medium is prepared, in which the fungi can thrive under certain known conditions. To this medium, which usually consists of agar agar mixed with some nutrient such as beef broth, are added known amounts of the preservative, and the whole is poured into shallow covered glass dishes known as Petri dishes. After the agar agar has solidified to a jelly, it is inoculated with the fungus or other organisms to be used in the test. The organisms that have been used in testing wood preservatives include molds, yeast, timber-destroying fungi, and bacteria. The objection to the use of molds, yeasts, and bacteria for testing wood preservatives is that the killing points for these organisms might be entirely different from that for timber-destroying fungi, and it is already known that timber-destroying fungi differ among themselves in their resistance to certain wood preservatives. The chief advantage is that the test can be made in a few days instead of the weeks necessary when timber-destroying fungi are used. Although this difference in behavior in the various kinds of low organisms tested must be recognized, the information obtained from these comparative tests performed with such cultures is not entirely without value; for the experiments give very quickly some general idea of the relative toxicity, and approximately indicate the order in which the toxicity may reasonably be expected to fall when the preservatives are tested against timber-destroying fungi.

Humphrey and Fleming (29), of the Forest Products Laboratory, and Dean and Downes (30), of the Sheffield Scientific School, have put this work on safer ground by using the timber-destroying fungi in their tests. The former, who have done by far the greatest amount of work and have used chiefly the fungi *Fomes annosus* and *F. pinicola*, place the toxic point of coal-tar creosote between 0.2 and 0.5 per cent. If this is the true toxic point, then one-fifth of a pound of creosote per cubic foot of wood, provided it were properly distributed, would be sufficient to stop the growth of the fungi.

CAUSE OF TOXICITY OF CREOSOTE.

There is now little or no data on what compound or compounds in coal-tar creosote are responsible for its toxic effect, because few of the constituents have been isolated and subjected to tests. In general, the constituents of coal-tar creosotes may be divided into three groups—the hydrocarbon oils, the tar acids, and the tar bases. Of the hydrocarbons that are found in coal-tar creosote, naphthalene and anthracene, according to the methods used by J. M. Weiss (31), seem to have very little toxic action against bacteria, yeast, and penicilium. Russell and Pendleton (32) have shown that benzene and toluene are capable of destroying certain undesirable (or harmful) soil protozoa, bacteria, and fungi, but do not act on certain other soil bacteria that are desirable. Naphthalene and crude oil, when tested in the same way, gave a similar but slighter action. Weiss (31), Charitschkow (33), and Dean and Downes (30) have shown that the “neutral oils”—those oils that have been freed from tar acids and tar bases by being washed with caustic soda and sulphuric acid—still possess a considerable toxic property. Weiss (31) and Charitschkow (33) state that the toxicity of the neutral oils is nearly as great as the toxicity of the original creosotes from which they were obtained. Dean and Downes (30) show that the acid-free oil is more toxic than the original, but that the neutral oil (free from both acids and bases) is only about two-thirds as toxic as the original. The same sort of evidence has been obtained in the Forest Products Laboratory by Huntley (34), except that in his tests the toxicity of the neutral oils exceeded the toxicity of the original creosote. There is, of course, the possibility that the methods used to remove the tar acids and tar bases were such that there were traces of these materials or their salts still remaining in the oil, and that the increased toxicity of the tar-acid free oil of Dean and Downes and of the neutral oil of Huntley was due to the small amounts of tar-acid salts, which are somewhat more soluble in the agar medium than are the acids themselves. However, the weight of evidence now available seems to show that the neutral oils of coal-tar creosote are themselves very toxic, and that this toxicity is due to the lower-boiling hydrocarbons.

Of the tar acids and other oxygenated compounds found in coal-tar creosote, perhaps the best known is phenol, or carbolic acid. Phenol is recognized in medicine as being extremely toxic to practically all kinds of living organisms. It is used as a standard in the determination of the killing power of antiseptics and bactericides. The higher homologues of phenol, the cresols, are from two to four times as effective toward bacteria as is phenol, and the naphthols are also extremely toxic compounds which have been used as antiseptics and germicides. Weiss (31) has shown that the tar acids (all the tar acids extracted with caustic soda) are about as toxic as pure carbolic acid to penicillium, bacteria, and yeast, and that pure cresol is much stronger, requiring only a trace, whereas pure carbolic acid requires 0.15 per cent. Trillat (35) in 1892 mentioned phenol and alpha and beta naphthol as powerful antiseptics. Adiasiewietsch (36), in 1897, in experimenting with petroleum products, added tar acids among other things to increase the utilization of petroleum for wood preservation. Bokany (37) compared the efficiency of phenol with other antiseptics, and Schneider (38) has prepared powerful antiseptics from the alpha and beta naphthols as well as from the cresols. Russell and Pendleton (32) have shown that both the phenols and cresols are valuable for soil sterilization, although these operators found certain bacteria which apparently lived upon them. Morgan and Cooper (39), in 1912, showed that against the *Bacterium typhosum* the tar acids in general increase in toxicity with increase in molecular weight; and that in the same series of compounds, an increase in molecular weight is always accompanied by a rise in boiling point. They also show that the dihydroxynaphthalenes (2, 3, hydroxynaphthalenes and 2, 7, hydroxynaphthalenes), that is, naphthols having two phenolic groups, are between three and five times as toxic as phenols. It will be noted that the references given here are to comparatively recent experiments, some of which were directly connected with the wood-preserving industries. The references have been given to show that there are a number of investigators in wood preservatives who believe that coal-tar creosote owes its antiseptic properties, in a large measure at least, to phenols or tar acids.

The nitrogen bodies, that is, the pyridines, quinolines, and some others, have not been investigated so thoroughly as the phenols. Trillat (35) placed both quinoline and pyridine in the list of powerful antiseptics. Weiss (31) has shown that quinoline has decided antiseptic properties, being somewhat stronger than the phenols against the organisms tested. Morgan and Cooper (39) showed that the amines, that is, those compounds containing an NH_3 group, are, in general, toxic to the *Bacterium typhosum*, although not so toxic as the corresponding phenols. Here again, in the same series of com-

pounds, the toxicity increases with molecular weight and with rise in boiling point. Russell and Pendleton (32) have shown that both pyridine and quinoline are valuable for soil sterilization.

It is realized that these tests on the various constituents of coal-tar creosotes are not conclusive proof of the antiseptic action of these materials when they are applied to timber-destroying fungi. The tests do at least point out the way in which it is most probable that creosote produces its toxic effect, and it might reasonably be assumed that the various classes of compounds, when applied to fungi, will behave in much the same way as they did in the tests in which they were applied to various other lower organisms. This will be the more probable if the general conclusion can be substantiated by a considerable amount of data. Certain tests now being made at the Forest Products Laboratory show that the tar acids are extremely toxic to timber-destroying fungi; that the tar bases are as toxic to these fungi, if not more so; and that the higher hydrocarbons under test have at best a slight toxicity. It seems, therefore, that the conclusion is justified that creosote oil in a large measure owes its toxicity against timber-destroying fungi to the tar acids and tar bases which form a small part of its composition, the rest of the toxic effects being caused by the light oil. The heavier oils have but little toxic value for this purpose. This conclusion is further brought out by the curve (fig. 36) showing the toxicity of coal-tar creosote plotted against its volatility at 275° C.

TESTS ON MARINE BORERS.

Practically the only work of this nature on the toxicity of creosote and its constituents toward the marine borer that has been published is that of Dr. Shackell (40). He showed that the phenols were extremely poisonous to the *Xylotrya*, but that the hydrocarbons, naphthalene, and anthracene could apparently be taken in and ejected from the body of this marine borer with no ill effects upon the animal. In conformity with this result, he found that the lower fractions of creosote are more toxic, and that, as the boiling points of the fractions increase, the toxicities decrease.

COMPARISON WITH SERVICE TESTS.

It is of considerable interest to compare the results of toxicity tests with service tests on the same material. Fortunately, there is in the Forest Products Laboratory a series of fractions of coal-tar creosotes which have been tested by the Petri-dish tests for fungi, by laboratory tests for *Xylotrya*, and by service tests as piling. Table 26 shows such a comparison.

TABLE 26.—Comparison of laboratory toxicity tests and service tests on fractions of coal-tar creosote.

Material.	Boiling point at the still.	Relative position against <i>Fomes annosus</i> .	Relative position against <i>Xylotrya</i> .	Relative position in service.
Fraction 1.....	Below 205° C.....	2	1 1	2 6
Fraction 2.....	205° to 250° C.....	1 1	2	5
Fraction 3.....	250° to 295° C.....	3	3 and 4	4
Fraction 4.....	295° to 320° C.....	5	5	2 and 3
Fraction 5.....	Res. above 320° C.....	2 6	2 6	1 1
Coal-tar creosote L-54.....	Average creosote.....	4	3 and 4	2 and 3

¹ The figure 1 indicates the greatest toxicity or service.

² The figure 6 indicates the least toxicity or service.

Table 26 shows that the toxicity and length of service of the materials tested are almost completely reversed—that is, the highest toxicity gave the least service, and the least toxic substance gave the best service. The discrepancy between these two results is, however, easily explained. In order to exert its effect upon *Xylotrya*, the toxic principle must be soluble in the body fluids of this organism. In a state of purity these toxic principles would have a great and immediate toxic effect, but this effect would not be permanent, because the toxic principle is taken out by the continual leaching of the water. If, however, these toxic principles are mixed with oils in which they are more soluble than they are in water, it becomes increasingly harder to leach them, because of the retarding action of the oil. If, then, the toxic principles of coal-tar creosotes are considered to be chiefly the lower-boiling oils, it would be expected that in the Petri-dish tests, which are conducted with only a small amount of water, the fractions would arrange themselves in the order 1, 2, 3, 4, 5. But in service tests a greater loss would be expected from fraction 1 than from fraction 2, and a greater loss from fraction 3 than from fraction 4, and so on. The character of the residual oil in fraction 1 would tend to approach the character of the oil in fraction 5, and in the end the oils would be much the same in composition; fraction 1 would contain the least, and fraction 5 the most preservative, and the service tests would be expected to show the order 5, 4, 3, 2, 1. This was the actual arrangement in the service tests.

The separation of the fractions sharply into those indicated in Table 26 is by no means complete. Present knowledge of the action of complex mixtures upon distillation indicates that fraction 1 might be expected to contain considerable material which should have been included in fraction 2, a smaller amount which should have been included in fraction 3, and perhaps a small amount of fractions 4 and 5. Fraction 2 might be expected to contain considerable amounts of fractions 1 and 3, and smaller amounts of fractions 4 and 5. The truth of these statements is illustrated in Table 27, which

shows the percentage distilling from each fraction within the limits of the other fractions.

TABLE 27.—*Relative composition of fractions of coal-tar creosotes when redistilled by Hempel flask (30).*

Fraction No.	Amount distilling within the limits of—				
	Fraction 1.	Fraction 2.	Fraction 3.	Fraction 4.	Fraction 5.
1	Per cent. 63	Per cent. 37			
2	10	72	26	2	
3		22	52	20	6
4		1	22	31	46
5			3	21	76

A more refined analysis would, of course, increase the distillation range. Huntley has shown that on the redistillation of fraction 4 the following initial boiling points were obtained, the initial boiling point at the still having been 295° C.

	° C.
Initial boiling point of second distillation.....	270
Initial boiling point of third distillation.....	210
Initial boiling point of fourth distillation.....	140
Initial boiling point of fifth distillation.....	137

In other words, although the initial boiling point at the still was 295° C., this fraction contained a small amount of material boiling below 200° C. This amount was found to contain approximately 20 per cent of tar acids, and the amount boiling from 200° to 235° C., contained considerable quantities of tar bases. Both of these are very toxic materials and in the pure state are soluble in water; when mixed with oils in which they are soluble their extraction with water would take a very long time.

The two factors that govern the preserving value of any wood preservative are permanence and toxicity, but these two factors seem to be diametrically opposite. The relation between them is shown in figure 34.

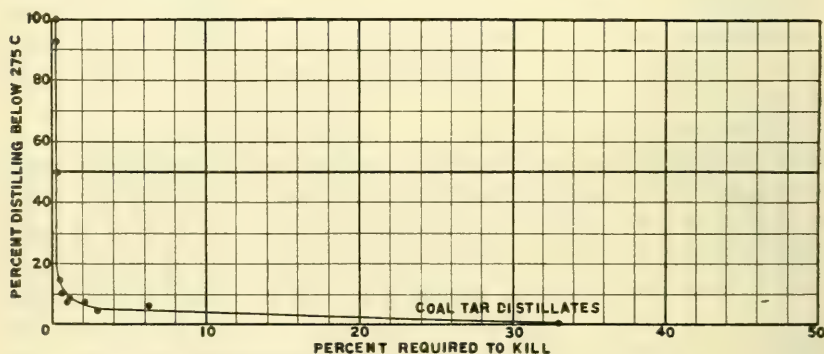


FIG. 34.—Relation between the volatility and toxicity of coal-tar creosotes.

CHAPTER IV. COMPOSITION AND PROPERTIES OF WATER-GAS-TAR CREOSOTES.

COMPOSITION OF WATER-GAS-TAR-CREOSOTES.

The distillate oils of water-gas tar boiling above 200° C. and as high, sometimes, as 400° C. are referred to as water-gas-tar creosotes. Like the coal-tar creosotes, they are extremely complex mixtures, composed chiefly of compounds of the aromatic series. They usually contain compounds of the aliphatic series, but this is by no means a characteristic of all water-gas-tar creosotes. The amounts may vary from nothing to as high as 20 or 25 per cent, depending chiefly on the temperature of formation of the mother liquor, tar. The results of much less research work have been published on water-gas tar and its products than on coal tar; consequently much less is publicly known about this material.

The similarity of water-gas-tar creosote and coal-tar creosote makes it seem very probable that in general the hydrocarbons found in the highly aromatic water-gas tars are the same as those found in coal tars. Benzol, toluol, xylol, naphthalene, phenanthrene, and methyl anthracene have been identified. The most notable difference between coal-tar creosotes and water-gas-tar creosotes is the nearly total absence of tar acids and tar bases in the latter and their presence in considerable amounts in the former. On account of the lack of these materials the odor of water-gas-tar creosotes is more oily than the odor of coal-tar creosotes.

CHEMICAL PROPERTIES OF WATER-GAS-TAR CREOSOTES.

The chemical properties of water-gas-tar creosotes are in general the same as those of coal-tar creosotes from which the tar acids and tar bases have been removed. Only a very small proportion is reacted upon by caustic soda or dilute mineral acids. Concentrated sulphuric acid forms many sulphonic acids which are identical with the sulphonic acids produced from coal-tar creosotes.

PHYSICAL PROPERTIES OF WATER-GAS-TAR CREOSOTES.

Because of the great similarity between water-gas-tar creosotes and coal-tar creosotes, the physical properties of one material would in general be the same as those of the other. The same solvents can be used for both. In general, the color of water-gas-tar creosote is somewhat more greenish, although this does not always hold true. The specific gravity of water-gas-tar creosotes is somewhat lower than the specific gravity of coal-tar creosote, varying between 1 and 1.07 at room temperature.

VOLATILITY.

The volatility of three water-gas-tar creosotes is shown in figure 31D. Here the loss by volatilization is plotted against the percentage distilling at 270° C. These data were obtained from hemlock treated with water-gas-tar creosotes and held under test for 80 days at a temperature of 40° C. The conditions of these tests were the same as those described in connection with figure 31B, for coal-tar creosotes. The same general result is obtained from these creosotes as from coal-tar creosote, namely, that the volatility increases in some direct ratio to the percentage distilling below 270° C. The character of the

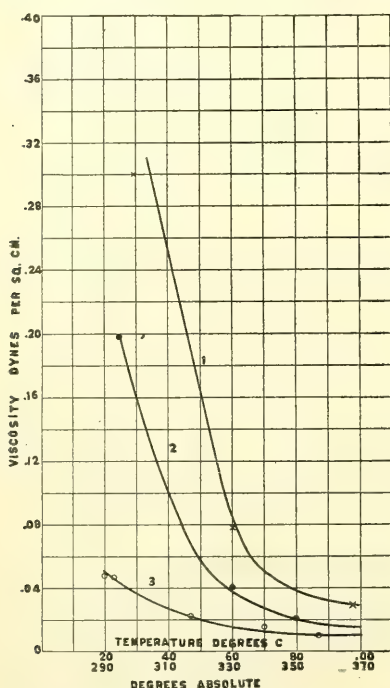


FIG. 35.—Change in viscosity of water-gas-tar creosotes with change in temperature. 1. Very high boiling oil. 2. Similar to a high-boiling creosote. 3. Low-boiling oil.

VISCOSITY.

The change in viscosity with a rise in temperature for three water-gas-tar creosotes of widely different characteristics is shown in figure 35. The creosotes are pure distilled products without the addition of any tar. The change in viscosity of water-gas-tar creosotes with change in temperature can be calculated in the same manner as that of coal-tar creosotes according to the equation, $\frac{V}{T^A} = K$, where V is the absolute viscosity, T the absolute temperature, and K and A are constants depending upon the oil. The equations,

test, whether from open pan or from treated wood, whether of short or long exposure, and the temperature of heating will, of course, affect the volatility in the same general manner as in coal-tar creosote. Different results would probably also be obtained if different species of wood were used. A comparison of the two curves, which are comparable as far as treatment, wood, temperature of heating, and length of exposure are concerned, reveals the fact that the volatility of water-gas-tar creosote is the same as that of coal-tar creosote having the same percentage of distillate below 270° C. It follows, therefore, that the discussion of the volatility of coal-tar creosotes will apply equally well to water-gas-tar creosotes.

for the three curves in figure 35 are,

$$(1) V = \frac{6.02(10)^{31}}{T^{13}} \quad (2) V = \frac{3.4(10)^{31}}{T^{13}} \quad (3) V = \frac{8.94(10)^{17}}{T^{7.8}}$$

TOXIC PROPERTIES OF WATER-GAS-TAR CREOSOTES.

One might expect that the toxicity of water-gas-tar creosotes would be somewhat less than the toxicity of coal-tar creosotes because of the absence of tar acids and tar bases. This, in general seems to be true. The killing points of a few authentic water-gas-tar creosotes produced in the Forest Products Laboratory vary from 0.3 per cent to approximately 1 per cent against the timber-destroying fungus *Fomes annosus*. Dean and Downes (30) have investigated water-gas-tar creosotes and compared them with coal-tar creosotes. Their investigations with the timber-destroying fungus *Polystictus versicolor* show that the water-gas-tar creosotes used in their tests were about as toxic as the coal-tar creosotes which they used. These investigations also showed that the coal-tar creosote, after being freed from tar acids and tar bases, was only two-thirds as toxic as the original creosote or the water-gas-tar creosotes with which they compared it. The water-gas-tar creosotes were about twice as toxic as the high-boiling anthracene oils obtained from coal tar. J. M. Weiss (31) has shown that water-gas-tar creosotes are not so toxic against yeast, molds, and bacteria as the coal-tar creosotes which he tested.

The work of these investigators may be criticised not only because of their method of determining the toxicity, but also because they did not compare creosotes of similar boiling points. Dean and Downes, for instance, compared the toxicity of creosotes having the distillation limits shown in Table 28.

TABLE 28.—Comparison of the percentages of distillates of the creosotes whose toxicities were compared by Dean and Downes.

Fraction.	Coal-tar creosote.	Water-gas-tar creosote.
	<i>Per cent.</i>	<i>Per cent.</i>
Up to 205° C...	6.5	10.0
Up to 240° C...	37.2	45.5
Up to 300° C...	53.5	73.0
Up to 320° C...	67.6	84.0

The water-gas-tar creosote has a much lower boiling point than has the coal-tar creosote, and, consequently, it should be more toxic than the neutral oil of the coal-tar creosote. Weiss compared the oils as shown in Table 29.

TABLE 29.—Comparison of the percentages of distillates of the creosotes whose toxicities were compared by Weiss.

Fraction.	Straight coal-tar creosote.	Maintenance of way creosote.	Neutral coal-tar creosote sp. gr. 1.037.	Water-gas-tar creosote sp. gr. 1.024.	Water-gas-tar creosote sp. gr. 1.053.
Up to 200° C.	6.6	.....	1.8	1.1	.....
Up to 235° C.	60.3	33.2	30.6	18.9	5.3
Up to 270° C.	76.5	60.5	63.4	50.2	24.3
Up to 315° C.	86.2	78.0	87.2	81.4	49.0

All the coal-tar creosotes, even the neutral creosote, had lower boiling points than the water-gas creosotes, and consequently they should be more toxic than the water-gas-tar creosotes.

Tests made at the Forest Products Laboratory indicate that water-gas-tar creosotes, particularly the lower boiling ones, have a considerable degree of toxicity. A relation of toxicity to volatility similar to that found in coal-tar creosotes holds in the case of water-gas-tar creosotes also, except that the latter are not as toxic as the former, particularly so in the higher boiling oils that are analagous to carbolineums. The relation between toxicity of water-gas-tar creosotes and their volatility is shown in figure 36.

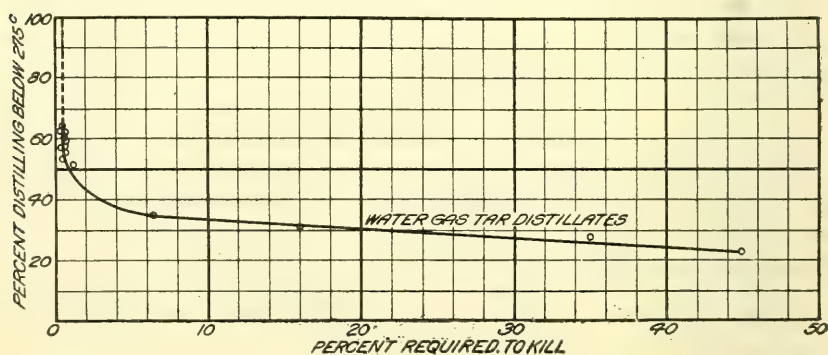


FIG. 36.—The relation between volatility and toxicity of water-gas-tar creosotes.

CHAPTER V.—COMPARISON OF THE PROPERTIES OF COMMERCIAL COAL-TAR CREOSOTES AND COMMERCIAL WATER-GAS-TAR CREOSOTES.

It is believed that a short comparison of the properties of commercial oils will be of value, notwithstanding the fact that they have been discussed at some length in the preceding chapters. Table 30 shows the similarities and dissimilarities of coal-tar creosotes and water-gas-tar creosotes.

TABLE 30.—Comparison of the properties of commercial coal-tar creosotes and commercial water-gas-tar creosotes.

	Coal-tar creosote.	Water-gas-tar creosote.
Specific gravity of original creosote.....	1.01 and up.....	1.00 and up.....
Flash point.....	70° C. and up.....	70° C. and up.....
Burning point.....	90° C. and up.....	90° C. and up.....
Distilling range.....	170 to 400° C.....	170 to 400° C.....
Change in specific gravity per degree C.....	0.00078.....	0.00078.....
Sulphonation residue of fractions 275° to 285° C.....	0 to 8 per cent.....	0 to 8 per cent.....
Tar-acid content.....	Up to 10 per cent.....	None.....
Character of hydrocarbon.....	Chiefly aromatic.....	Chiefly aromatic.....
Ratio of specific gravity to index of refraction of the fraction 275° to 285° C.....	1.81.....	1.56.....
Toxicity.....	Shown in fig. 37.....	

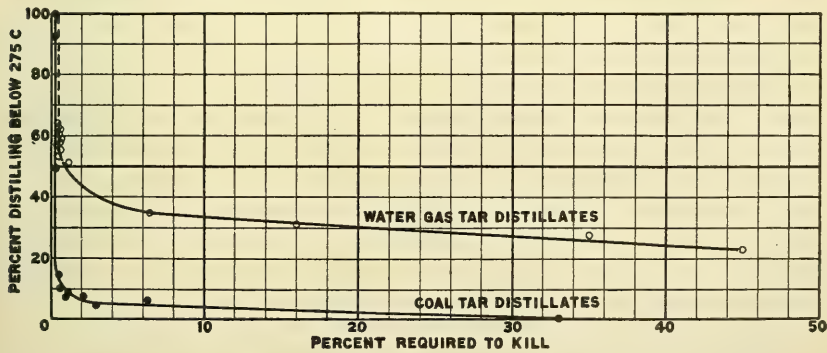


FIG. 37.—Comparison of the toxicities of coal-tar creosotes and water-gas-tar creosotes.

The chief difference between these two classes of creosote are a total lack of tar acids and bases in the water-gas-tar creosotes, a higher general average of the sulphonation residues in water-gas-tar creosotes than in coal-tar creosotes, and a lower toxicity. (Fig. 37.) The only methods known at the forest products laboratory for differentiating between two classes of oils are the determination of

the tar-acid and tar-base contents, the determination of the ratio of the specific gravities to the indices of refraction values of the various fractions, and the testing of the toxicity of the creosotes. The absence of tar acids or tar bases is proof that the oil under test is not a distillate of coal tar. Part of the tar acids or tar bases may be removed from coal-tar creosote by chemical methods, but it is not likely that all the tar acids and all the tar bases would be taken out by such means. On the other hand, the presence of tar acids or tar bases or both classes of compounds does not mean that the oil under examination is a pure coal-tar distillate. It may be a water-gas-tar oil which has been mixed with a coal-tar creosote containing large amounts of tar acids and bases, or these materials may have been added directly to water-gas-tar creosote. The determination of the ratio of the specific gravities of the fractions to their index of refraction values is of use only if it is known that the distillates are pure oils, either water-gas-tar or coal-tar distillates. Unknown mixtures of the two can not be differentiated with certainty by this method. The toxicity test is of value only in high-boiling oils similar to carbolineum. In lower-boiling oils the fraction similar to carbolineum might be tested, but because of the fact that six weeks are required for its completion this test is of little value for commercial purposes.

CHAPTER VI. TAR-CREOSOTE SOLUTIONS.

Within the last few years tar-creosote solutions have been used more and more in wood preservation. Various claims have been put forward in favor of tar: First, that, as it is the mother liquor of creosote, it contains all the toxic principles of creosote; second, that it retards the evaporation of creosote when mixed with it; third, that it does not reduce penetration into the wood; and fourth, that it is cheaper than coal-tar creosote. In answer to these arguments it may be said that, although tar is the mother liquor and contains all the toxic principles of coal-tar creosote, the concentration of the toxic elements in coal tar is only about one-fourth of that in coal-tar creosote, because coal-tar creosote is only about one-fourth of the volume of the coal tar from which it is distilled and contains practically all the toxic principles. It has also been shown in this bulletin that coal tar does not retard the evaporation of creosote mixed with it. Furthermore, Bond (17), and Teesdale and MacLean (18) have demonstrated that it is more difficult to penetrate wood with coal-tar solutions than it is with creosote.

TAR AS A DILUENT.

The chief value of tar is as a diluent of creosote, although it may have a retarding influence on the rate of solution of the toxic principles into the wood. The use of a diluent in wood preservation is no new thing. In the treatment of wood with zinc chloride a strength of solution is used that will insure a thorough penetration. If the wood is difficult to penetrate, a relatively strong solution is used; but, if it is easy to penetrate, a more dilute solution is used, and more solution is put in, thus insuring a more thorough treatment. In other words, the amount of water or solvent is varied, but the amount of zinc chloride is kept constant. With zinc chloride the factor of safety is only about 2; with creosote it is in the neighborhood of 50. The reason for this great difference is that by diluting zinc chloride with water a depth of penetration as great as possible is obtained, and still only a small amount of zinc is used. On the other hand, it is impossible to give a deep oil penetration without using large quantities of oil. However, the usual oil penetration could be obtained, and at the same time creosote could be saved if it were diluted with some other oil, and this would have an effect analogous to that of the water in a zinc-chloride solution. As any good solvent of creosote would serve as well as another for this purpose, the main

thing is to obtain the cheapest material that will meet the conditions. Benzene and chloroform would answer the requirements so far as physical and chemical conditions are concerned, and on drying they would evaporate just as water does; but their use is, of course, out of the question on account of their great cost. Wood-preservers are practically confined by cost to such crude raw oils as crude petroleum, coal-tar, or water-gas tar. Of these three, coal-tar and water-gas tar are better solvents of creosote than is crude petroleum. Of the two tars, water-gas tar seems for the following reasons to fulfill more nearly all the requirements of a diluent:

(1) It contains an exceedingly small amount of suspended matter, whereas coal tar, as a minimum, has about 3 or 4 per cent. The viscosity of water-gas tar is usually less than that of coal tar. A mixture of water-gas tar and creosote may, therefore, be expected to penetrate more rapidly than an equal mixture of coal tar and coal-tar creosote.

(2) It may be used in its raw state when it is free from water. Coal tar containing ammonia was found by Bolton to be injurious to wood; therefore it must be refined in order to remove the ammonia.

(3) Crude water-gas tar, water free, is cheaper than refined coal tar.

Inasmuch as service records (27) show that the failures so far experienced in ties, poles, and other timbers have been the result of mechanical wear, checking, and similar causes, and not of the failure of the preservative, it is apparent that the limit of the life of coal-tar creosote has not been reached in this kind of service. In other words, the factor of safety is probably very much larger than it need be. It would seem justifiable in such conditions to dilute the creosote with some cheaper material, such as tar, to make the life of the preservative and the mechanical life of the wood more nearly equal. The best kind of oil to use for dilution under such conditions would be the low-boiling creosotes, because these contain the greatest amount of toxic materials. If the theory of the mechanism of preservative action suggested in this bulletin is correct, these low-boiling creosotes probably need more high-boiling materials to retard their too rapid solution.

PROPERTIES OF TAR-CREOSOTE SOLUTIONS.

But little can be said about the properties of tar-creosote solutions except that they should be intermediate between the same properties of creosote and tar. A small amount of work has, however, been done and the results of it are given below:

SPECIFIC GRAVITY.

The addition of a heavier substance, such as tar to creosote will, of course, increase the average specific gravity of the solution. This

increase in gravity appears to be a straight-line relation depending upon the gravity of the oil, the gravity of the tar, and the proportion of each in the mixture. The gravity of any solution may, therefore, be calculated from the gravity of its two components by the following formula: Specific gravity solution = per cent tar (specific gravity tar) + per cent creosote (specific gravity creosote). Figure 38 shows the change in specific gravity of a creosote with the addition of various amounts of a tar. The curve is drawn from the equation; the points are from experimental data.

COEFFICIENT OF EXPANSION.

No data are available on the coefficient of expansion of tar solutions; but it would seem probable that the factor could be calculated from the known values for the change in the specific gravities of creosote and tar, respectively, on the assumption that the factor will be in direct proportion to the percentages of each of the two components in the mixture. J. M. Weiss (15) has published the results of investigations on the coefficient of expansion of tars from various sources, and shows that the average coefficient of expansion from 60° F. to 140° F. varies from 0.00027 to 0.000375 per degree Fahrenheit, the former

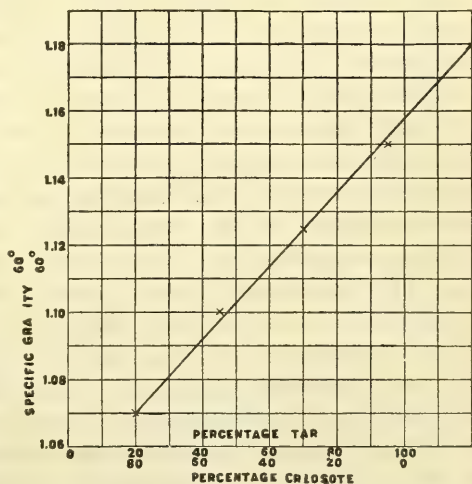


FIG. 38.—The change in specific gravity of tar solution.

being for a tar having a specific gravity of 1.296 and the latter for a tar having a specific gravity of 1.073. If these data be recalculated to a change in specific gravity per degree Fahrenheit, the factor will vary between 0.00035 and 0.00040, with an average of 0.000375. If, then, this factor be taken for the change in specific gravity of tar, and the factor 0.00043 be taken for the change in the specific gravity of creosote oil, the factors shown in Table 31 will be the change in specific gravities of tar mixtures, and should give results close enough to the true value for all commercial purposes.

TABLE 31.—*Change in specific gravity of different mixtures of tar and coal-tar creosote.*

Mixture contains—		Change in specific gravity per degree Fah- renheit.
Tar.	Creosote.	
<i>Per cent.</i>	<i>Per cent.</i>	
10	90	0.00042
20	80	.00042
30	70	.00041
40	60	.00041
50	50	.00040

VOLATILITY.

The question has been raised whether or not evaporation can be partially prevented by the addition of some such nonvolatile material as tar, the tar having some sort of binding or holding property which would prevent the creosote from evaporating as rapidly as if it were used alone. In one of their papers, Von Schrenk and Kammerer (25) give a number of curves showing the loss by evaporation of creosote, tar, and creosote-tar mixtures. The tests extended over a long period of time, namely, 1,000 days, or nearly 3 years. The curves show that the tar is less volatile than the creosote-tar mixtures, and that the latter are less volatile than the creosote. If, however, the results are plotted in the same way as those of the creosote test (fig. 31), the same relation between volatility and percentage of distillate up to 270° C. will be shown. Furthermore, the volatility of the creosote-tar mixture can be calculated from the known volatility of the creosote and tar. The calculation is extremely simple and consists in multiplying the volatility of each constituent by the percentage used in the mixture and taking the sum of the two products as the volatility of the mixtures. Calculations made in this manner show the results given in Table 32.

TABLE 32.—*Comparison of actual and calculated losses due to evaporation of tar and coal-tar creosote mixtures.*

Loss of creosote.	Loss of tar.	Tar mixtures.	Calcu- lated loss of mixtures.	Actual loss.
<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
48.8	9.5	70 p. ct. C., 30 p. ct. T.	37.0	38.0
46.2	9.0	80 p. ct. 20 p. ct.	38.8	40.4
46.2	9.0	70 p. ct. 30 p. ct.	35.0	37.8
65.0	6.0	80 p. ct. 20 p. ct.	53.2	51.8
50.8	5.6	80 p. ct. 20 p. ct.	41.8	41.8
59.6	10.9	80 p. ct. 20 p. ct.	49.8	48.6

Table 32 shows that the actual loss and the calculated loss are practically identical. In other words, the effect of the tar is simply to reduce the quantity of creosote in the test, and the percentage

loss is based on an increased weight resulting from the addition of tar. The same general conclusion that the volatility of the creosote itself is practically not affected by the addition of the tar has been reached by Fredendoll (42) with respect to high-boiling petroleum oils.

VISCOSITY.

The addition of tar to coal-tar creosote of course increases the viscosity. The increase is not, however, in direct proportion to the amount of tar added. Up to about 50 per cent of tar the increase is relatively small, but beyond that point the viscosity increases very rapidly. Figure 39 shows the effect upon the viscosity of adding

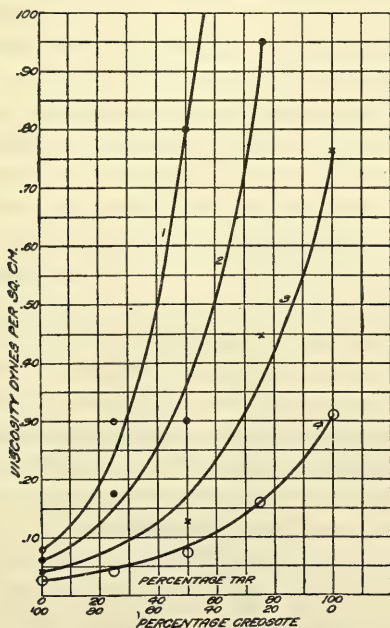


FIG. 39.—Change in viscosity of tar solutions with different amounts of tar at various temperatures.

1—At 40° C. 2—At 50° C. 3—At 70° C.
4—At 90° C.

tar to creosote at different temperatures. The viscosity of any solution of coal tar and creosote may be calculated from the viscosity of the tar and the viscosity of the creosote at the same temperature by the aid of the formula $V_m = \left(\frac{P}{V_t} \right) (V_c^{1-P})$, where V_m = viscosity of the solution, V_t = viscosity of the tar, V_c = viscosity of the creosote, P = percentage tar used expressed as a decimal.

In figure 39 the value of a 50 per cent solution of tar and creosote at 90° C. is obtained from the equation $V_c = (0.31^{0.5}) (0.025^{0.5})$.

CHAPTER VII. A THEORY OF THE MECHANISM OF THE PROTECTION OF WOOD BY OIL SOLUTIONS.

The author has recently proposed a theory of the mechanism of the protection of wood by preservatives, which is based on the two ideas, first, that any material in order to be toxic must be soluble in the body fluids of the organism it is intended to inhibit, and second, that, as the body fluids of timber-destroying organisms are chiefly water, the material must be soluble in water, at least sufficiently so to produce a solution of lethal concentration. For the purposes of this theory all the constituents of creosote oil may be divided into two classes. The first class comprises those materials that are sufficiently soluble in water to render them poisonous. These may be called toxic oils. They may be hydrocarbons, such as benzene, toluene, xylene, naphthalene, etc.; or tar acids, such as cresols, naphtols, etc.; or tar bases, such as quinoline, isoquinoline, etc.; or a combination of all three. Their chief characteristic is that they are sufficiently soluble in water to render their water solution capable of killing the wood-destroying organism. The second class of compounds comprises those that are not sufficiently soluble to render their water solutions toxic. This class of oils may be composed of the same types of compounds as those previously enumerated, and these oils differ from those of the other class only in their relative solubility. They may even be soluble to a slight extent, and in all probability they are. This class may be called nontoxic oils.

The toxic oils are completely soluble in the nontoxic oils and are partially soluble in water. When creosote comes in contact with water, these toxic oils will so divide themselves between the water and the nontoxic oils that their concentrations in water and in the nontoxic oil will be nearly in proportion to their solubility in the two mediums. This is known as the solubility partition. For the sake of argument, a toxic oil may be assumed which is fifty times as soluble in the nontoxic oil as it is in water, and it may be assumed that a 10 per cent solution of this toxic oil is used in the nontoxic oil. When such a solution comes in contact with an equal volume of water, the concentration of the water solution will be 0.2 per cent. If now the toxic limit of this water solution is only 0.05 per cent, then the water solution will be four times as toxic as is necessary to kill. It may be assumed that this water is now withdrawn and an equal amount added, which in turn takes up its proportion of toxic oil and is rendered poisonous. This change of water can take place seventy times

before the concentration of the water is below the killing point, and even then the water solution would still be very poisonous, though not sufficiently strong to kill, for at least 30 more changes of water.

In actual practice this change may take place either rapidly or slowly, depending upon the location of the treated timber. If the timber is alternately exposed to wetting and drying, as is true of piling between high and low tide, a very high rate of solution with rapid depletion of the preservative material would be expected. In timber located in dry places, as, for instance, telephone poles, a very much slower rate of solution would be expected. The idea here is simply that one part of the creosote oil prevents the rapid solution of the other part of the creosote oil which is toxic and which acts as the preservative.

The information in support of this theory is as yet incomplete in respect to creosote oil; but what information there is confirms the theory. Historically, perhaps the first data available on the solubility partition was furnished by Boulton in the Appendix of his *Antiseptic Treatment of Timber*, in which he showed that tar acids could be washed out of creosote by water. This, of course, is true, and according to the theory here proposed it is necessary if protection is to be afforded by tar acids. Boulton does not, however, make a point of showing that, although he used only 20 ounces of oil, it required 32 washings and the use of three times as much water as oil, or a total of 1,920 ounces, to reduce the tar-acid content of the oil from 10 per cent to 1.5 per cent in one case, and from 17.5 per cent to 3.5 per cent in the other case. In other words, he used 96 times as much water as he did oil, and even then he did not remove all of the tar acids. The attack of the teredo on treated piling after long service, during which the creosote acted as a preservative, is certainly a sure indication that the action of the water had dissolved out certain portions of the oil that were toxic. If this had not been so, the teredo would have begun its attack immediately. The very fact that creosote oil protected for a time and then failed to protect is sufficient indication that the toxic element had been removed.

A better proof of the theory is shown by some recent investigations at the Forest Products Laboratory. In the course of a certain study it was necessary to extract the creosote from a few telephone poles that had been in service about 20 years. One of these poles was so checked at the ground line as to permit the entrance of fungi, and the entire center of the pole at the ground line was completely decayed. None of the wood that contained creosote was decayed; in fact, it was very noticeable that there was a ring of from one-fourth to one-half inch in the untreated wood just inside the treated portion which was in a perfectly sound condition. This ring of

wood had been preserved from the fungus attack in some way or other, although it apparently contained no creosote. Sections of this untreated but preserved wood were taken, and any portions that showed signs of containing creosote were carefully removed. The remainder of the wood was then reduced to sawdust. A portion of this was extracted with water in a Soxhlet extractor in such a way as to retain the tar acids, if any were present, in the water. Another portion treated in the same manner was extracted, but in such a way as to retain the tar bases, if any were present. The solutions thus obtained, upon being neutralized, gave odors similar to those obtained from tar acids in the one case and from tar bases in the other. A second extraction with benzol of the wood previously extracted with water gave a residue of perfectly clear rosin, in which there was not the least sign of creosote odor. From this it seems apparent that this inner ring of untreated material had been preserved by the water-soluble material that came from the creosote and had been diffused through the wood. On the other hand, from coal-tar creosote a high-boiling oil has been isolated, which is probably a mixture of anthracene, phenanthrene, acenaphthene, and their hydrides. This oil is practically nontoxic, for fungus grows on agar agar containing 20 per cent of the oil.

The theory assumes that any toxic material which is more soluble in oil than it is in water will be less toxic at the start if oil is present than it would be in its absence. That is, if it takes 0.05 per cent of some material in water alone to kill an organism, it might take as much as 2 per cent if the material were dissolved in oil. On the other hand, any reserve material would not be removed so rapidly by leaching in the presence of oil as in its absence. Under similar conditions the speed at which creosote will be rendered nontoxic by leaching will depend on two things—the relative solubility of the toxic oils in the nontoxic oils and in water and the proportion of nontoxic oils present. If too little of the nontoxic oils is present, then the toxic material will be washed away very rapidly, because there would be little or no retaining influence exerted by the nontoxic oils. On the other hand, if there is too large an amount of nontoxic oil, the toxic oils will be prevented from going into solution in the water in a sufficient concentration to kill the attacking organism, and consequently these oils would not act as preservative.

PART IV. METHODS OF TESTING CREOSOTES AND OFFICIAL SPECIFICATIONS FOR CREOSOTE.

CHAPTER I. PRACTICAL METHODS OF TESTING CREOSOTES.

A number of tests have been proposed for creosote which, in general, are of considerable service when materials of known source are to be examined. The tests fail, however, if an attempt is made to determine whether the creosote under test meets the requirements for purity. The following tests have been proposed and used.

SPECIFIC-GRAVITY TEST.

Practically all specifications for creosote require that it shall have a certain range of specific gravity; sometimes it is stated that the specific gravity shall not be less than 1.03 or more than 1.08, and sometimes that it shall not be less than 1.03. The specific-gravity determination is effective only when straight distilled oils are used. Water-gas-tar oils have practically the same range. An oil of low specific gravity may be made to pass the specifications for coal-tar creosote by the addition of tar. This would also raise the distillation limits. The specific-gravity test, although it is an exceedingly useful one when used with creosotes of known origin, does not identify the oil or exclude tar. Any approved method of determining specific gravity will answer. An ordinary hydrometer is generally used. The dimensions of the hydrometer and cylinder, and the details of the test adopted as standard by the American Society for Testing Materials, the American Railway Engi-

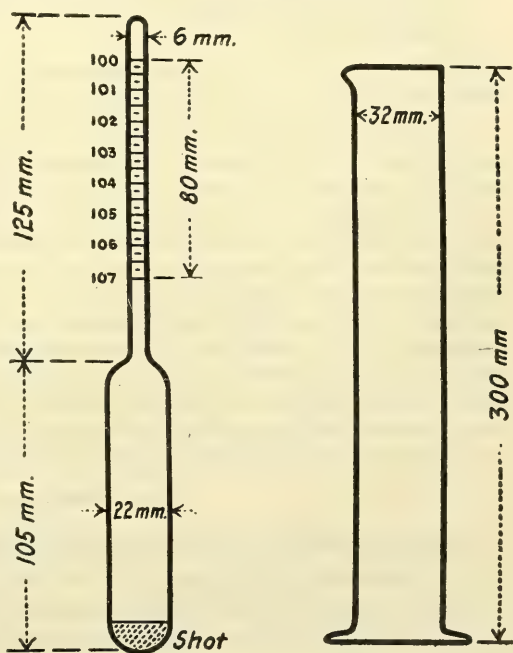


FIG. 40.—Hydrometer and cylinder used for specific-gravity test.

neering Association, and the American Wood Preservers' Association are as follows:

SPECIFIC GRAVITY.

(a) *Hydrometer*.—The hydrometer shall be of the form shown in figure 40. It shall have the following dimensions:

Length of stem.....	125 mm.; permissible variation.....	12.5 mm.
Length of bulb.....	105 mm.; permissible variation.....	10.5 mm.
Length of scale.....	80 mm.; permissible variation.....	8.0 mm.
Diameter of stem.....	6 mm.; permissible variation.....	0.5 mm.
Diameter of bulb.....	22 mm.; permissible variation.....	2.0 mm.

A set of two hydrometers with ranges 1.00 to 1.08 and 1.07 to 1.15 will suffice.

(b) *Cylinder*.—The cylinder shall be of the form shown in figure 40. It shall have the following dimensions:

Length.....	300 mm.; permissible variation.....	30 mm.
Diameter.....	32 mm.; permissible variation.....	3 mm.

The oil shall be brought to a temperature of 38° C. (100° F.), and the determination shall be made at the temperature unless the oil is not entirely liquid at 38° C. In case the oil requires to be brought to a higher temperature than 38° C. in order to render it completely fluid, it shall be tested at the lowest temperature at which it is completely fluid, and a correction made by adding 0.0008 to the observed specific gravity for each degree centigrade above 38° C. at which the test is made. This correction factor does not apply with equal accuracy to all oils, but serious error due to its use will be avoided if the foregoing precaution is observed with respect to avoiding unnecessarily high temperature. Before taking the specific gravity the oil in the cylinder should be stirred thoroughly with a glass rod, and this rod when withdrawn from the liquid should show no solid particles at the instant of withdrawal. Care should be taken that the hydrometer does not touch the sides or bottom of the cylinder when the reading is taken, and that the oil surface is free from froth and bubbles.

FREE-CARBON TEST.

The determination of free carbon or insoluble matter was supposed to be a measure of the amount of tar that might be present. When tar was obtained chiefly from gas houses this test did, in a rough way, give an indication of the amount of coal tar present in creosote. If 5 per cent of the tar containing 20 per cent of the free carbon were mixed with a pure distilled creosote, then the mixture would contain about 1 per cent of free carbon. In modern coke-oven practice tars may run as low as 4 per cent free carbon. Twenty-five per cent of such tar could be mixed with creosote and the mixture would still have only 1 per cent of free carbon. Furthermore, water-gas tar containing no free carbon could be added in any proportion without being identified by the free-carbon test.

The free-carbon test has been conducted by a number of different methods. In general it depends on the solubility of the oils in some

such substances as carbon bisulphide, chloroform, benzol, or toluol. Different results are obtained by the use of different solvents because the hydrocarbons of creosote or tar are not uniformly soluble in these solvents. This is particularly true of the bitumens in the pitches.

J. M. Weiss has conducted a number of tests on tar with different solvents. His method of procedure was to allow tar to digest with cold solvent for a number of hours and then to filter off the undissolved portion and extract it with the boiling solvent. When benzol,

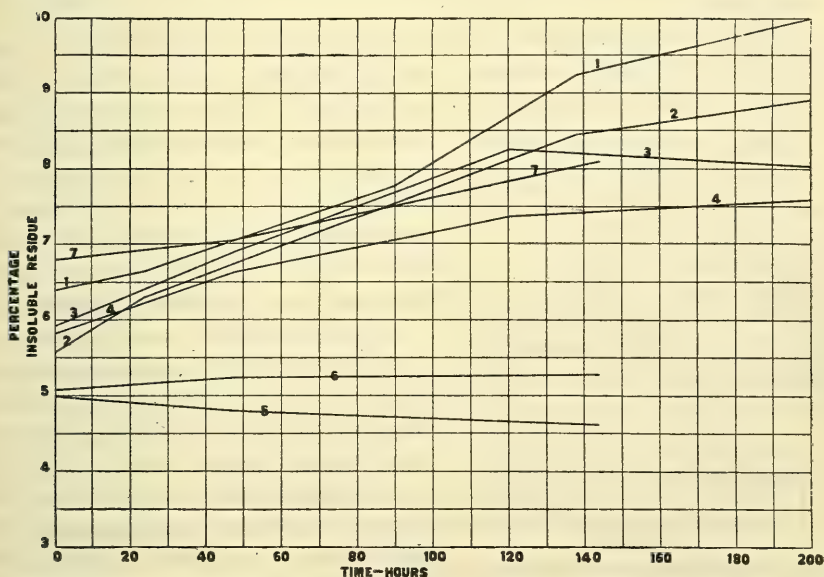


FIG. 41.—Change in apparent free-carbon content of a tar with change in time of digestion with different solvents.

- | | |
|------------------------------------|--------------------------------------|
| 1. Insoluble in benzol. | 5. Insoluble in aniline. |
| 2. Insoluble in benzol and toluol. | 6. Insoluble in pyridine. |
| 3. Insoluble in chloroform. | 7. Insoluble in glacial acetic acid. |
| 4. Insoluble in carbon bisulphide. | |

benzol and toluol, chloroform, or carbon bisulphide was used as the cold extractive the same material served as the hot extractive; but when he used aniline, pyridine, or glacial acetic acid as a cold extractive he followed them with benzol as a hot extractive. The data obtained have been plotted in figure 41. From these curves it is apparent that the insoluble matter in this tar after one-half hour's digestion varied from 5 to 6.6 per cent, but that after 144 hours' digestion it varied from 4.6 to 9.3 per cent. With the exception of

the method in which glacial acetic acid was employed, that in which benzol was used as a solvent gave the highest results. All the solvents except aniline gave higher results with longer digestions. With the use of aniline the insoluble matter decreased from 5 per cent after one-half hour to 4.6 per cent after 144 hours, and this was the lowest result obtained.

Weiss further showed that the insoluble residue, after digestion with chloroform, contained noticeable amounts of chlorine. Sulphur was also found in the residue resulting from the digestion with carbon bisulphide.

Monroe and Broderson (45) investigated the action of benzol and chloroform on the free-carbon content of three classes of tar. The results of their work are plotted in figure 42. Here again they found

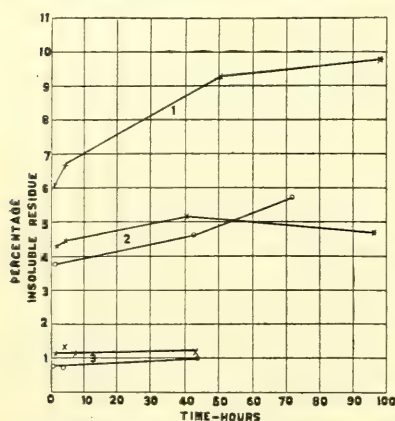


FIG. 42.—Change in apparent free carbon content of tars with change in time of digestion.

Numbers represent tars No. 1, 2, and 3.

X. Extractions made with benzol.

O. Extractions made with chloroform.

that benzol yields a greater insoluble residue than does chloroform, notwithstanding the fact that considerable quantities of chlorine were found in the residue. This amount increased with the time of digestion.

From the above it is apparent that, if this test is designed to determine the free carbon in tars, a digestion with aniline would give the more nearly correct result. But if a purely empirical determination is all that is desired, then any one of the solvents is satisfactory provided that the test is made standard and the conditions of the test are defined and rigidly adhered to.

The method adopted as standard by the American Society for Testing Materials, the American Railway Engineering Association, and the American Wood Preservers' Association is as follows:

Apparatus.—(A) Extractor may be of the form shown in figure 43 or similar form in which the oil is subjected to direct washing by the boiling vapors of the solvent.

(B) Filtering medium may be either two thicknesses of S. and S. No. 575 or Whatman No. 5 hardened filter paper, 15 cm. in diameter, arranged in cup shape by folding symmetrically; or alundum thimbles, flat bottom, 30×80 RA 98. If filter papers are used they shall be soaked in benzol prior to using to remove grease, dried in a steam oven, and kept in a desiccator until ready to be used. The filter-paper cup may be suspended in the extractor flask by a wire basket hung from two small hooks on the under surface of the metal cover of the flask.

If the alundum thimble is used it may be supported by making two perforations in the top of the thimble and suspending from the cover by German silver or platinum wires.

Method.—Weigh 10 grams of dry creosote in 100 cc. beaker. Add about 50 cc. of pure benzol and transfer at once to the filter cup. The filter cup or thimble is previously weighed, and the paper cup shall always be kept in a weighing bottle until ready for use. Wash out the beaker with benzol, passing all washings through the filter cup and place the latter at once in the extraction apparatus.

Extractor shall contain a suitable quantity of pure benzol. Sufficient heat to boil the solvent shall be provided by means of an electric heater or a steam bath.

Continue the extraction until the descending solvent is practically colorless and remove the filter cup and dry in steam oven until all solvent is driven off; cool in desiccator and weigh. The balance used for this purpose should be accurate to 0.5 mg.

DAVIS SPOT TEST.

T. H. Davis (46), in 1909, proposed a test, which he called the spot test, for the preliminary testing of creosote oil for free carbon. This test has been used for a long time by distillers, and consists in placing 6 drops of the oil on blotting paper and noting the character of the spots which remain. If free carbon is present it will manifest itself by a ring of free carbon the same size as the spot, but the oil will spread out into a ring 1 to 2 or $2\frac{1}{2}$ inches in diameter. This test is exceedingly delicate and shows the presence of very minute quantities of carbon; for this reason it is of small value for determining the amount of free carbon in creosotes. It will, however, show whether the regular free-carbon determinations should be made, and is of value as a preliminary test for this purpose. The test itself has not been given by creosote chemists the attention it deserves. H. Cloukey (47) shows that the test may be applied for a preliminary examination and will give a good indication to the analyst of what he may expect to find in the creosote under examination. When the color, character, and size of the spot are taken into consideration remarkable approximations may be made, provided a large number of authentic spots are available. Pure coal-tar creosote, pure water-gas-tar creosote, coal tar, water-gas tar, wood tar, wood-tar creosote, and petroleum oils all give spots that are characteristic of themselves and different from the others. Mixtures of creosote with tars also give characteristic spots.

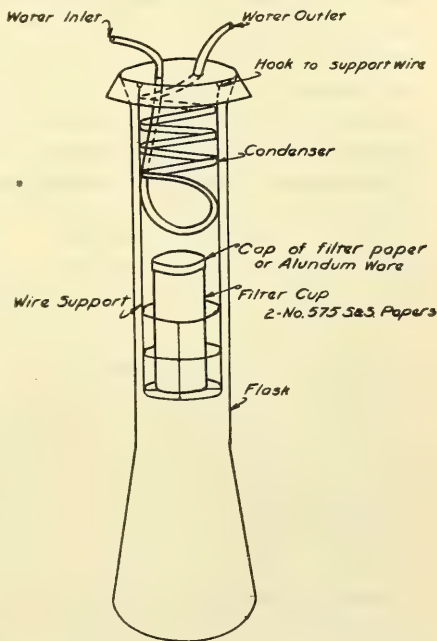


FIG. 43.—Type of extractor recommended for "free carbon" test.

COKE TEST.

The coke test was proposed by the National Electric Light Association (48) for the determination of the amount of admixed tar, and was later adopted by the American Wood Preservers' Association and the American Society for Testing Materials. It depends upon the amount of coke residue left after all the volatile matter has been driven off. The coke residue in itself gives only a rough approximation of the amount of tar that has been added, for the coke residues of coal tars may vary anywhere from 26 to 57 per cent, while those of water-gas tars vary from 18 to 28 per cent. As usually applied, this test favors the use of water-gas tar in tar solutions in preference to coal tar. If, however, the free-carbon content (matter insoluble in benzine) is subtracted from the coke residue the resulting figure, which may be termed the "bituminous-coke residue," is fairly constant for both water-gas tar and coal tar, as is shown in Table 33.

TABLE 33.—*Free-carbon content, coke residues, and bituminous-coke residues of various tars (49).*

Kind of tar.	Tar No.	Free-carbon content.	Coke residue.	Bituminous-coke residue.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
High or medium free-carbon tar.....	1	37.1	57.2	20.1
	2	18.6	43.5	24.9
	3	16.2	42.9	26.7
	4	15.4	34.4	19.0
Low-carbon coal tar.....	5	7.6	26.8	19.2
	6	6.7	27.0	20.3
	7	5.4	28.4	23.0
	8	5.2	30.6	25.4
	9	4.4	29.4	25.0
Water-gas tar.....	10	1.3	25.3	24.0
	11	1.1	28.1	27.0
	12	.1	23.2	23.1
	13	.....	18.2	18.2

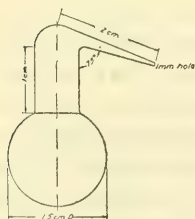


FIG. 44.—Bulb used in making coke test.

The method of conducting the coke test, as recommended by the three societies, is as follows:

The bulb shall be of hard glass, as shown in figure 44, and shall have the following approximate dimensions:

	Mm.
Diameter of bulb.....	15
Length of vertical neck.....	10
Length of horizontal neck.....	20
Diameter of orifice.....	1

Warm the bulb slightly to drive off all moisture, cool in a desiccator, and weigh. Again heat the bulb by placing it momentarily in an open Bunsen flame, and place the tubular underneath the surface of the oil to be tested, and allow the bulb to cool until sufficient oil is sucked in to fill the bulb about two-thirds full.

Any globules of oil sticking to the inside of the tubular should be drawn into the bulb by shaking or expelled by slightly heating it, and the outer surface should be

carefully wiped off and the bulb reweighed. This procedure will give about 1 g. of oil.

Cut a strip of thin asbestos paper about one-fourth inch wide and about 1 inch long, place it around the neck of the bulb, and catch the two free ends close up to the neck with a pair of crucible tongs. The oil should then be distilled off as in making ordinary oil distillation, starting with a very low flame and conducting the distillation as fast as can be maintained without spurting.

When oil ceases to come over, the heat should be increased until the highest temperature of the Bunsen flame is attained, the whole bulb being heated red hot until evolution of gas ceases, and any carbon sticking to the outside of the tubular is completely burned off. The bulb should then be cooled in a desiccator and weighed and the percentage of coke residue calculated to water-free oil.

DISTILLATION TEST.

This test has been used nearly as long as specifications have been written for creosote. It is without value for the determination of the source of the oil, because coal-tar creosote, water-gas-tar creosote, blast-furnace oil, certain crude petroleums, shale oils, candle oils, acid residues, and certain others have practically the same range of boiling points. The only value of the distillation test alone is to determine whether an oil of known source meets the requirements of the specification so far as boiling points are concerned. The type of distilling vessel has a considerable influence on the percentage of distillate obtained in any fraction from a given creosote. Because of the exceeding complexity of the mixture, no single distillation can secure an absolutely true apportionment of the oil, no matter how refined the apparatus may be. Therefore, to get concordant results from different operators, it is necessary that the standard form of the distilling vessel should be accurately fixed, that the position of the thermometer should always be the same, that the rate of distillation should be uniform, and that thermometers having practically the same dimensions should be used. The types of vessel that have been proposed for this test are the 8-ounce retort, the ordinary distilling flask, the Lunge trap flask, and the Hempel flask. The first three are used for ordinary commercial work and the last for a more refined test. The first three, when used under standard conditions, will give practically the same average results. The choice of one of the three vessels for such an empirical operation as the distillation test rests, therefore, on the ability of the apparatus to duplicate results. The ability to do this depends on the exact reproduction of the form, shape, and size of the apparatus. As the retorts are blown by hand in the form of a long pear-shaped glass and then bent down in a flame, the shapes and sizes can not be kept uniform. As a result, a so-called 8-ounce retort may hold anywhere from 4 to 12 ounces, depending on the carefulness of the assortment. On the other hand, as flasks of glass are now blown in a mold, the shapes and sizes are practically uniform. One would, for this reason,

expect the flasks to give more concordant results than the retorts, and this, in general, is true.

The Forest Products Laboratory has shown (50) that, although there is no practical difference between the average numerical results obtained by the use of the flask and retort, the flask gives a somewhat sharper separation than the retort and is therefore to be preferred to the retort.

The argument advanced in favor of the retort is that it has been used up to this time and should be continued. The argument against it is that it does not give as concordant results as the flask, and that the flask gives practically the same numerical value. Two associations—the National Electric Light Association (51) and the American Railway Engineering Association (52)—have made tests on the comparative checking value of the flask and the retort. The data obtained by them are published in their proceedings. A careful survey of these data shows that, after the elimination of what are evidently experimental errors, the ordinary flask is superior to the retort in checking value.

OFFICIAL SPECIFICATIONS OF FOUR SOCIETIES.

The specifications for the distillation tests adopted as standard by the American Wood Preservers' Association (1917), the American Railway Engineering Association (1917), the American Society for Testing Materials (1918), and the National Electric Light Association (1921), are as follows:

Retort.—This shall be a tubulated glass retort of the form and approximate dimensions shown in figure 45 with a capacity of 250 to 290 c. c. The capacity shall be measured by placing the retort with the bottom of the bulb and the end of the off-take in the same horizontal plane, and pouring water into the bulb through the tubulature until it overflows the off-take. The amount remaining in the bulb shall be considered its capacity.

Condenser tube.—The condenser tube shall be a suitable form of tapered glass tubing of the following dimensions:

Diameter of small end.....	12.5 mm.; permissible variation.....	1.5 mm.
Diameter of large end.....	28.5 mm.; permissible variation.....	3.0 mm.
Length.....	360.0 mm.; permissible variation.....	4.0 mm.

Shield.—An asbestos shield of the form shown in figure 45 shall be used to protect the retort from air currents and to prevent radiation. This may be covered with galvanized iron, as such an arrangement is more convenient and more permanent.

Receivers.—Erlenmeyer flasks of 50 to 100 c. c. capacity are the most convenient form.

Thermometer.—The thermometer shall conform to the following requirements: The thermometer shall be made of thermometric glass of a quality equivalent to suitable grades of Jena or Corning make. It shall be thoroughly annealed. It shall be filled above the mercury with inert gas which will not act chemically on or contaminate the mercury. The pressure of the gas shall be sufficient to prevent separation of the mercury column at all temperatures of the scale. There shall be a reservoir

above the final graduation large enough so that the pressure will not become excessive at the highest temperature. The thermometer shall be finished at the top with a small glass ring or button suitable for attaching a tag. Each thermometer shall have for identification the maker's name, a serial number, and the letters "A. S. T. M. distillation."

The thermometer shall be graduated from 0 to 400° C. at intervals of 1° C. Every fifth graduation shall be longer than the intermediate ones, and every tenth graduation beginning at zero shall be numbered. The graduation marks and number shall be clear-cut and distinct.

The thermometer shall conform to the following dimensions:

Total length, maximum.....	385	mm.
Diameter of stem.....	7	mm.; permissible variation..... 0.5 mm.
Diameter of bulb, minimum.....	5	mm.; and shall not exceed diameter of stem.
Length of bulb.....	12.5	mm.; permissible variation..... 2.5 mm.
Distance, 0° to bottom of bulb...	30	mm.; permissible variation..... 5 mm.
Distance, 0° to 400°.....	295	mm.; permissible variation..... 10 mm.

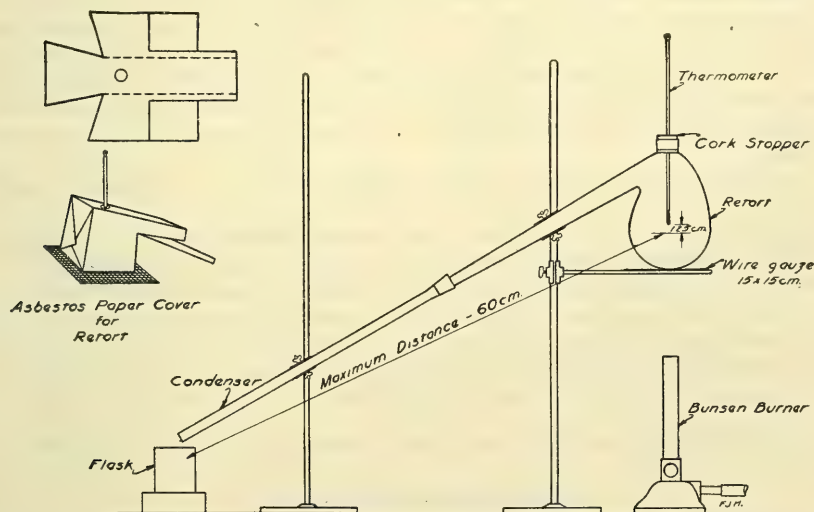


FIG. 45.—Arrangement of distilling apparatus recommended by American Wood Preservers' Association, American Railway Engineering Association, and American Society for Testing Materials.

The accuracy of the thermometer when delivered to the purchaser shall be such that when tested at full immersion the maximum error shall not exceed the following:

	° C.
From 0° to 200° C.....	0.5
From 200° to 300° C.....	1.0
From 300° to 375° C.....	1.5

The sensitiveness of the thermometer shall be such that when cooled to a temperature of 74° C. below the boiling point of water, at the barometric pressure at the time of test and plunged into free flow of steam, the meniscus shall pass the point 10° C. below the boiling point of water in not more than six seconds.

The retort shall be supported on a tripod or rings over two sheets of 20-mesh gauze, 6 inches square. It shall be connected to the condenser tube by a tight cork joint. The thermometer shall be inserted through a cork in the tubulature with the bottom

of the bulb one-half inch from the surface of the oil in the retort. The exact location of the thermometer bulb shall be determined by placing a vertical rule graduated in divisions not exceeding one-sixteenth inch back of the retort when the latter is in position for the test, and sighting the level of the liquid and the point for the bottom of the thermometer bulb. The distance from the bulb of the thermometer to the outlet end of the condenser tube shall be not more than 24 or less than 20 inches. The burner should be protected from drafts by a suitable shield or chimney.

Exactly 100 g. of oil shall be weighed into the retort, the apparatus assembled, and heat applied. The distillation shall be conducted at the rate of at least one drop and not more than two drops per second, and the distillate collected in weighed receivers. The condenser tube shall be warmed whenever necessary to prevent accumulation of solid distillates. Fractions shall be collected at the following points: 210°, 235°, 270°, 315°, and 355° C. The receivers shall be changed as the mercury passes the dividing temperature for each fraction. When the temperature reaches 355°, the flame shall be removed from the retort, and any oil which has condensed in the off-take shall be drained in the 355° fraction.

The residue shall remain in the retort with the cork and the thermometer in position until no vapors are visible; it shall then be weighed. If the residue is to be further tested, it shall then be poured directly into the brass collar used in the float test, or into a tin box, and covered and allowed to cool to air temperature. If the residue becomes so cool that it can not be poured readily from the retort, it shall be reheated by holding the bulb of the retort in hot water or steam, and not by the application of flame.

For weighing the receivers and fractions, a balance accurate to at least 0.05 g. shall be used.

During the progress of the distillation the thermometer shall remain in its original position. No correction shall be made for the emergent stem of the thermometer.

When any measurable amount of water is present in the distillate it shall be separated as nearly as possible and reported separately, all results being calculated on a basis of dry oil. When more than 2 per cent of water is present, water-free oil shall be obtained by separately distilling a larger quantity of oil, returning to the oil any oil carried over with the water, and using dried oil for the final distillation.

A more refined test, in which the Hempel flask is used, is given in Part II.

MOISTURE IN CREOSOTE TEST.

It sometimes happens that it is necessary to make a determination of the moistures in creosote. If the moisture content is small (less than 2 per cent), this can readily be done in conjunction with the distillation test. If, however, the water exceeds 2 per cent, or if there is difficulty in carrying out the distillation test on account of the spattering, the following method should be used. It has been adopted as standard by the American Wood Preservers' Association, the American Railway Engineering Association, and the American Society for Testing Materials.

WATER.

Still.—A vertical, cylindrical copper still with removable flanged top and yoke of the form and approximate dimensions shown in figure 46 shall be used.

Thermometer.—The standard distillation thermometer as specified under "Distillation," shall be used.

Condenser.—A copper trough condenser shall be used with straight-walled glass tube, having approximately the form and dimensions shown in figure 46.

Separatory funnel.—A separatory funnel of the form shown in figure 46 shall be used, having a total capacity of 120 c.c., and the outlet graduated in fifths of a cubic centimeter.

The apparatus shall be set up as shown in the figure.

When any measurable amount of water is present in the distillate below 210° C. on testing in accordance with the distillation, the oil and water in this fraction shall be separated, if possible, and measured separately. If more than 2 per cent of water is present, or if the water is apparently present to an extent in excess of 2 per cent, but an accurate separation is impossible, the percentage of water present shall be determined by the following method, and the water-free oil so obtained shall be used in the distillation test:

Measure 200 c.c. of oil in graduated cylinder, and pour into copper still, allowing the cylinder to drain into the still for several minutes. Attach lid and clamp, using

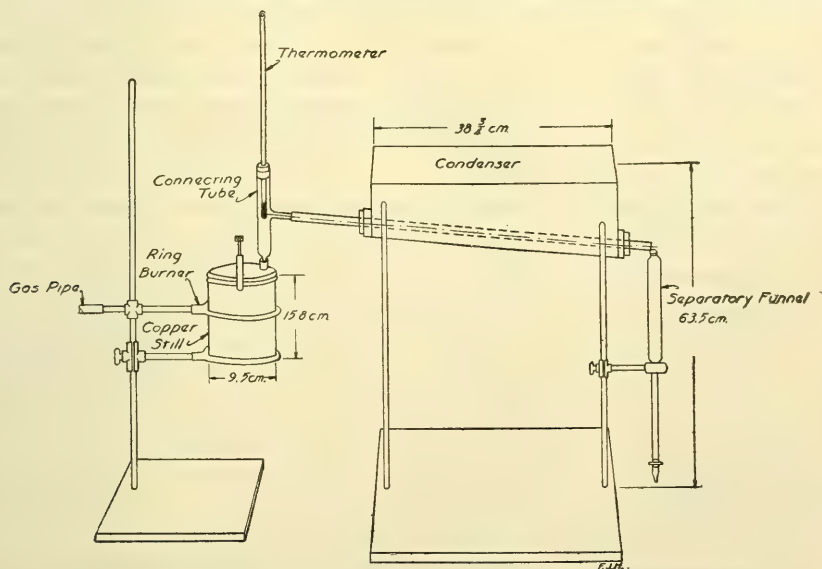


FIG. 46.—Apparatus for determining moisture content of creosote oil.

a paper gasket slightly wet with oil around the flange of the still. Apply heat by means of the ring burner, which shall be placed just above the level of the oil in the still at the beginning of the test, and gradually lowered when most of the water has distilled over. Continue the distillation until the vapor temperature, indicated by the thermometer with the bulb opposite the offtake of the connecting tube, reaches 205° C. Collect distillate in separatory funnel. When the distillation is completed, and a clear separation of water and oil in the funnel has taken place, read the water by volume and draw off; and return any light oil distilled over with the water to the oil in the still. The dehydrated oil from the still shall be used for the distillation test.

TEST OF THE SPECIFIC GRAVITY OF THE FRACTIONS.

The test of the specific gravity of the fractions has been adopted by the American Wood Preservers' Association, the American Society for Testing Materials, and the American Railway Engineering Association. Tests that may be applied to the fractions obtained in the

distillation of creosote are much more likely to eliminate admixtures than tests performed on the whole sample. Therefore, too much importance can not be attributed to this test. The specific gravity of the fractions, according to the latest specifications, is taken at 38° C. and referred to water at 15° C. In general, the same result would be obtained by determining the specific gravity at 60° C. and referring to water at 60° C. The data on specific gravity and index of refraction given in the part of this bulletin describing the experimental comparison of creosotes were all taken at 60° C., and referred to water at the same temperature. The present specifications require the specific gravity of two large portions 235° to 315° C. and 315° to 355° C.; and, whereas the results obtained by these two fractions seem to be very good, a closer control is obtained by the use of more fractions. On account of the fact that tars and creosotes having very different boiling points are sometimes mixed together, the failure of either fraction to fulfill the requirements of the specification should be sufficient cause for the rejection of the material under that specification.

The specific-gravity values of three pure coal-tar creosotes are given in Table 34.

TABLE 34.—*Specific gravities of fractions of three pure coal-tar creosotes.*

Type of creosote.	Fraction 235° to 315° C. Sp. gr. 38° 15°	Fraction 315° to 355° C. Sp. gr. 38° 15°
High-gravity creosote.....	1.047	1.145
Average-gravity creosote.....	1.036	1.112
Low-gravity creosote..... (Very exceptional cases.)	1.025	1.108

The examples from the report of the Committee on Preservatives of the American Wood Preservers' Association, 1917, given in Table 35, show the necessity of requiring both specific gravities to conform to the specification.

TABLE 35.—*Specific gravities of fractions of mixtures of coal-tar creosote, coal tar, and water-gas tar.*

No.	Composition of mixture.			Fraction 235° to 315° C. Sp. gr. 38° 15°	Fraction 315° to 355° C. Sp. gr. 38° 15°	No.	Composition of mixture.			Fraction 235° to 315° C. Sp. gr. 38° 15°	Fraction 315° to 355° C. Sp. gr. 38° 15°
	Creosote.	Coal tar.	Water-gas tar.				Creosote.	Coal tar.	Water-gas tar.		
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>				<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>		
1	65	25	10	¹ 1.028	1.102	7	65	.....	35	1.042	1.120
2	90	.....	10	1.033	¹ 1.088	8	55	.....	45	1.038	1.112
3	65	20	15	1.031	¹ 1.090	9	65	20	15	1.041	1.112
4	65	20	15	1.033	¹ 1.085	10	65	10	25	1.038	1.106
5	60	25	15	¹ 1.028	1.101	11	65	.....	35	1.038	1.104
6	55	22.5	22.5	¹ 1.025	1.100						

¹ Indicates failure to pass specifications.

Out of 28 tar solutions whose content of water-gas tar ranged from 10 to 45 per cent, 16 were rejected because both fractions were low in gravity, and 7 because one fraction was low; 5 passed both tests. Of these last, 1 was eliminated on account of both float and coke tests, 1 failed to pass the float test, and 1 failed in the coke test; but 2 passed all tests. Of these last, 1 contained 65 per cent of creosote, 20 per cent of coal tar, and 15 per cent of water-gas tar; and the other contained 65 per cent of creosote and 35 per cent of water-gas tar.

The method of determining specific gravity of the fractions recommended by the American Society for Testing Materials, the American Wood Preservers' Association, and the American Railway Engineering Association is as follows:

As specific gravity is an absolute physical determination, any recognized method which can be applied to the quantity and quality of material at hand to be tested must be considered satisfactory. The following methods are convenient and accurate means for the relatively small amounts of oil available in determining specific gravity of fractions to be tested.

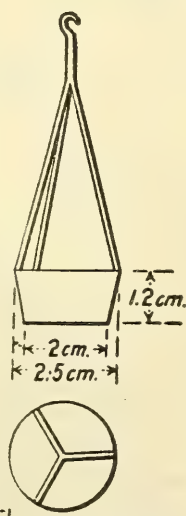
Liquid fractions.—The Westphal balance may be used. If the fraction to be tested is liquid at a temperature not exceeding 60° C., the Westphal balance can be used with convenience and rapidity. A special type of Westphal balance is obtainable, designed for testing very small quantities. However, the ordinary type of Westphal balance can be adapted to testing small fractions by the use of a special plummet. When using the ordinary balance with the special plummet, extra care is needed that the adjustment of the balance be accurately made. The plummet can readily be made in the laboratory from a piece of ordinary glass tubing 7 mm. outside diameter, sealed at the end, and by melting into the glass where sealed, a short platinum wire. After cooling, place 9 to 10 g. of mercury in the tube, making a column 35 to 40 mm. high. Seal off the tube within 20 mm. of the top of the mercury column with blow pipe flame. The plummet shall have a length of about 55 to 60 mm. over all, and shall weigh between 10 and 12 g.

Solid and semi-solid fractions.—A pan of the form shown in figure 47 having the following approximate dimensions, may be used:

Diameter of base.....	20 mm.
Diameter of top.....	25 mm.
Depth.....	12 mm.
Diameter of wire.....	1 mm.
Total weight.....	7 g.

The pan and wires are made of platinum or nickel.

Solid or semisolid fractions of oil which can not be readily liquified can be rapidly and accurately tested in this apparatus by the usual method of weighing in air and in



10415M-1

FIG. 47.—Pan used for determining specific gravity of solid or semi-solid fractions of creosotes.

water. The usual precautions of igniting the pan before use, and avoiding the enclosure of air or water in the sample, should be observed.

NOTE.—The method for liquid fractions is usually applicable to the fractions 235° to 315° C. and the method for solid and semisolid fractions to the fraction 315° to 355° C.

FLOAT TEST.

The float test is used for the detection and limitation of the amount of tar in creosote or creosote-tar solutions. It has been adopted by the American Wood Preservers' Association, the American Railway Engineering Association, and the American Society for Testing Materials. The apparatus consists of an asphalt viscosimeter made of a float or saucer of aluminum and two conical brass collars. In making the test a brass collar is filled with the residue left after distillation of the oil up to 355° C. It is then immersed in ice water for

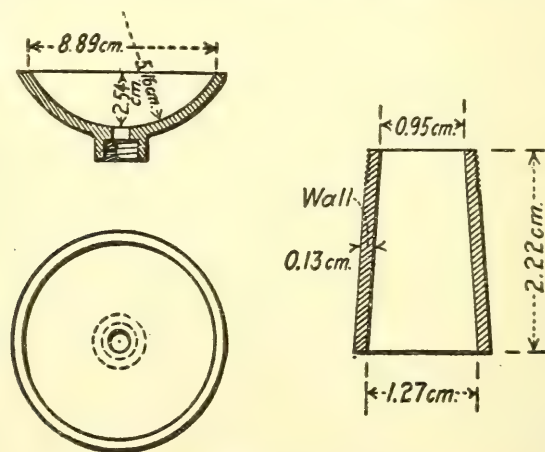


FIG. 48.—Apparatus used in float test.

a time sufficient to chill it thoroughly, after which it is fitted into the saucer and floated on water that is heated to the temperature of the test. The time in seconds, taken from the time the saucer is placed in the warm water to the time when it breaks through the plug of tar is a measure of the viscosity of the residue at the selected temperature and hence a measure of the amount of pitch or tar contained in the sample under test. This test can not be relied upon absolutely because of the variability in the amount of residue above 355° C. The chances are, however, that some other test, such as the free-carbon test, or the coke-residue test, or the test of the specific gravity of the fractions, would eliminate such oils, although in many cases 45 per cent or more of tar may be accepted under a specification permitting only 35 per cent.

The method of conducting the float test recommended by the three societies is as follows:

Float or saucer.—The float or saucer shall be made of aluminum, and shall be of the form and dimensions shown in figure 48.

Conical collar.—The conical collar shall be made of brass, and shall be of the form and dimensions shown in figure 48.

Place the brass collar with the small end on the brass plate, which has been previously amalgamated with mercury by first rubbing it with dilute solution of mercuric chloride or nitrate and then with mercury. Pour the residue to be tested into the collar direct from the retort, as described in the paragraph on "Distillation" or heat it in a tin box on water or steam bath, not by direct application of flame, and then pour into the collar in any convenient way until slightly more than level with the top. The surplus may be removed after the material has cooled to room temperature by means of spatula or steel knife which has been slightly heated. Then place the collar and plate in one of the tin cups containing ice water maintained at $5^{\circ}\text{C}.$, and leave in this bath for at least 15 minutes.

Meanwhile, fill the other cup about three-fourths full of water and place on the tripod; heat the water to any desired temperature at which the test is to be made. This temperature should be accurately maintained, and should at no time throughout the entire test be allowed to vary more than $0.5^{\circ}\text{C}.$ from the temperature specified.

After the material to be tested has been kept in the ice water for at least 15 minutes, and not more than 30 minutes, remove the collar with its contents from the plate and screw into the aluminum float, which is then immediately floated in the warmed bath. As the plug of residue becomes warm and fluid, it is forced upward and out of the collar until the water gains entrance to the saucer and causes it to sink.

The time in seconds between placing the apparatus on the water and when the water breaks through the residue shall be determined by means of a stop watch, and shall be taken as a measure of the consistency of the material under examination.

TAR-ACID CONTENT TEST.

Of late years the tar-acid test has not been applied to creosote to so great an extent as formerly. It can not be used for identification purposes, because tar acids may easily be added to products that do not contain them, and such adulterations can not now be detected. A mixture of 15 per cent of blast-furnace oil with 85 per cent of certain water-gas-tar creosotes will pass the tar-acid test, the specific-gravity test, and the distillation test for coal-tar creosotes.

The method of determining the tar acids adopted by the National Electric Light Association (51) is as follows:

One hundred cubic centimeters (100 c. c.) of the total distillate to three hundred and fifteen degrees ($315^{\circ}\text{C}.$) to which forty cubic centimeters (40 c. c.) of a solution of sodium hydroxide having a specific gravity of one and fifteen hundredths (1.15) is added, is warmed slightly and placed in a separatory funnel. The mixture is vigorously shaken, allowed to stand until the oil and soda solutions separate, and the soda solution containing most of the tar acids drawn off. A second and third extraction is then made in the same manner, using thirty (30) and twenty (20) cubic centimeters of the soda solution, respectively. The three alkaline extracts are united in a two-hundred cubic centimeter (200 c. c.) graduated cylinder, and acidified with dilute sulphuric acid. The mixture is then allowed to cool and the volume of tar acids noted. The results should be calculated to percentage of original oil.

NAPHTHALENE TEST.

The naphthalene test described by Mann (53) is not, so far as is known at the Forest Products Laboratory, used in this country to any great extent. It consists in determining the melting point of

the naphthalene fraction. It may, however, be used by some of the manufacturers under the name of the limpid-point test. It gives some idea of the naphthalene content, especially that which will solidify in cooling.

The Forest Service described (50) a test for solids which included naphthalene and anthracene solids. A test somewhat similar (54) was afterwards adopted by the American Railway Engineering Association. So far as the author is aware neither of these tests is now used to any great extent.

VISCOSITY TEST.

The viscosity test has been proposed chiefly in connection with tar mixtures (25). It consists of a determination of the viscosity by the use of an Engler viscosimeter. This gives but little information as to the amount of tar present. Probably an estimate of the tar content fully as accurate may be made by one familiar with analyses of creosote by noticing the character and percentage of residue above a certain fixed point, as, for instance, 320° C. The latter procedure is applicable to water-gas tar, but the former is not. This test has now been dropped from specifications. It is believed, however, in the light of the relationship that exists between the penetration of oils and their absolute viscosity, that it would be a very desirable test to make for this purpose alone.

INDEX OF REFRACTION TEST.

A description of the apparatus used and the method of making the index of refraction test is given on page —.

SULPHONATION TEST.

A description of the sulphonation test and directions for making it are given on page —.

DIMETHYL-SULPHATE TEST.

The dimethyl-sulphate test was designed chiefly for use in light creosotes and as sheep dips. Chapin (55) claims that it gives more satisfactory results than the sulphonation test which it replaces. At the Forest Products Laboratory, however, with creosotes such as are used by wood preservers, the sulphonation tests have given the better results. Neither test apparently can be relied upon to differentiate water-gas tar products from coal-tar products.

CHAPTER II.—SPECIFICATIONS NOW IN FORCE BY VARIOUS ASSOCIATIONS.

During the last few years a concerted effort has been made in this country by various societies interested in wood preservation to adopt uniform specifications for wood-preserving oils. Such specifications have been adopted or have been proposed by several societies. In addition to these, other specifications are still in force which do not require all the latest tests. It is believed, however, that enough of the more modern specifications are given in Table 36 to answer most purposes; but, for the sake of simplification, only those are included which apply to different types of oil. No claim is made for the superiority of any of these oils. They differ only in boiling points. Although it has been generally believed that the higher-boiling oils are the most permanent, it has been shown that oils lighter than those of specification No. 3, if used in a proper manner, have outlasted the mechanical life of ties and poles. For land work, therefore, it seems to be largely a matter of personal opinion as to which of these oils is the best. It must be remembered that these specifications are for materials of known origin and are in addition to the requirement that the creosote shall be a coal-tar product. However, the tests given in these specifications do not guarantee a pure coal-tar product. Certain selected materials which are not derived from coal tar may pass all the tests; but the tests, if rigidly enforced, considerably reduce the amount of such materials. At the same time, certain pure coal-tar products are eliminated. The specification is intended to insure the type of oil which has proved of benefit. Until other materials have proved to be of value, or until our knowledge of the mechanism of protection by creosote has been enlarged, it is deemed advisable to exclude such materials from the best grade of oil, even though they are coal-tar products.

COAL-TAR SOLUTIONS.

As already stated, tar solutions can not be considered so good preservatives as pure coal-tar creosotes. They have not been in use sufficiently long for their worth to be conclusively proved. It seems reasonable, however, to expect that a mixture of coal tar and coal-tar creosote will eventually be obtained that will preserve wood up to the limit of its mechanical life. Just what proportion of creosote and tar such a mixture will contain is problematical. Table 37 gives the specifications for tar solutions now in force.

TABLE 36.—*Specifications for coal-tar creosotes.*

[All creosotes listed must be a distillate of coal-gas or coke-oven tar, and, in addition, must fulfill these requirements.]

Requirement.	Specification.			
	No. 1.	No. 2.	No. 3.	No. 4.
Moisture content.....	N. M. 3 p. ct. ¹	N. M. 3 p. ct.	N. M. 3 p. ct.	N. M. 3 p. ct.
Insoluble in benzol.....	N. M. 0.5 p. ct.	N. M. 5 p. ct.	N. M. 5 p. ct.	N. M. 5 p. ct.
Specific gravity at 38° C. referred to water at 15.5° C.....	N. L. 1.03 ²	N. L. 1.03	N. L. 1.03	N. L. 1.06
Distillates up to 210° C.....	N. M. 5 p. ct.	N. M. 8 p. ct.	N. M. 10 p. ct.	N. M. 5 p. ct.
Distillates up to 235° C.....	N. M. 25 p. ct.	N. M. 35 p. ct.	N. M. 40 p. ct.	N. M. 15 p. ct.
Specific gravity of fractions at 38° C. referred to water at 15.5° C.:				
Fraction 235° to 315° C.....	N. L. 1.03	N. L. 1.03	N. L. 1.03	N. L. 1.03
Fraction 315° to 355° C.....	N. L. 1.10	N. L. 1.10	N. L. 1.10	N. L. 1.10
The float test must not exceed 50 seconds at 70° C. if the residue at 355° C. exceeds.....	5 p. ct.	5 p. ct.	5 p. ct.	5 p. ct.
Coke residue.....	N. M. 2 p. ct.	N. M. 2 p. ct.	N. M. 2 p. ct.	N. M. 2 p. ct.

Specification No. 1=Grade 1, A. R. E. A.; creosote for ties and structural timber of A. W. P. A.

Specification No. 2=Grade 2, A. R. E. A.

Specification No. 3=Grade 3, A. R. E. A.

Specification No. 4=Distillate oil for paving blocks, A. W. P. A. and A. S. M. I.

¹ N. M.=Not more than.

² N. L.=Not less than.

TABLE 37.—*Specifications for coal-tar solutions.*

Requirements.	Specification No. 1.	Specification No. 2.
Composition of solution.....	80 per cent distillate of coal-gas or coke-oven tar; 20 per cent filtered or refined coal-gas or coke-oven tar.	65 per cent distillate of coal-gas or coke-oven tar; 35 per cent filtered or refined coal-gas or coke-oven tar.
Water content.....	N. M. 3 per cent ¹	N. M. 3 per cent.
Insoluble in benzol.....	N. M. 2 per cent.	N. M. 2 per cent.
Specific gravity at 38° C. referred to water at 15.5° C.....	N. L. 1.03 ²	N. L. 1.03.
Distillates up to 210° C.....	N. M. 1.12	N. M. 1.14.
Distillates up to 235° C.....	N. M. 5 per cent.	N. M. 5 per cent.
Distillates up to 235° C.....	N. M. 25 per cent.	N. M. 25 per cent.
Specific gravity of fractions at 38° C. referred to water at 15.5° C.:		
Fraction 235° to 315° C.....	N. L. 1.03	N. L. 1.03.
Fraction 315° to 355° C.....	N. L. 1.10	N. L. 1.10.
Float test must not exceed 50 seconds at 70° C. if the distillation residue at 355° C. exceeds.....	26 per cent.	35 per cent.
Coke residue.....	N. M. 6 per cent.	N. M. 10 per cent.

Specification No. 1= Tar solution for ties and structural timber of A. R. E. A. and A. W. P. A.

Specification No. 2= Tar solution for paving blocks of A. W. P. A. and A. S. M. I.

¹ N. M.=Not more than.

² N. L.=Not less than.

WATER-GAS TAR.

Up to the present time no specifications have been adopted for either water-gas tar or water-gas-tar creosotes to be used alone as a wood preservative. The American Railway Engineering Association adopted in 1920 a specification for water-gas tar distillate and a specification for water-gas tar solution to be used in conjunction with zinc chloride by any of the preserving processes employing both zinc chloride and oil. The requirements of these specifications are given in Table 38.

TABLE 38.—*Specifications for water-gas tar products to be used with zinc chloride.*

Requirements.	Distillate oil	Water-gas-tar solution.
Composition.....	A pure distillate of water-gas tar.	60 per cent distillate of water-gas tar; 40 per cent refined or filtered water-gas tar.
Water content.....	N. M. 3 per cent ¹	N. M. 3 per cent.
Insoluble in benzol.....	N. M. 0.5 per cent.....	N. M. 2 per cent.
Specific gravity at 38° C. referred to water at 15.5° C.	N. L. 1.02 ²	N. L. 1.03.
Distillates up to 210° C.....	N. M. 5 per cent.....	N. M. 1.07.
Distillates up to 235° C.....	N. M. 25 per cent.....	N. M. 8 per cent.
Distillates up to 355° C.....	N. L. 80 per cent.....	N. M. 20 per cent.
Specific gravity of fraction at 38° C. referred to water at 18.5:.....		N. L. 60 per cent.
Fraction 235° to 315° C.....	N. L. 0.98.....	N. L. 0.98.
	N. M. 1.02.....	N. M. 1.02.
Float test must not exceed 50 seconds at 70° C. if the distillation residue at 355° C. exceeds.	5 per cent.....	5 per cent.
Coke residue.....	N. M. 2 per cent.....	N. M. 10 per cent.

N. M.=Not more than.

² N. L.=Not less than.

APPENDIX.

TABLE 39.—*Distillation of authentic coal-tar creosotes.*

HORIZONTAL-RETORT TAR CREOSOTES.

Tar No.	Fraction limits.														Res.
	Up to 205° C.	205 to 215° C.	215 to 225° C.	225 to 235° C.	235 to 245° C.	245 to 255° C.	255 to 265° C.	265 to 275° C.	275 to 285° C.	285 to 295° C.	295 to 305° C.	305 to 315° C.	315 to 330° C.		
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
1	3.3	3.3	10.6	7.4	8.0	5.3	5.4	3.9	7.7	6.7	5.0	5.4	6.4	21.4	
2	5.0	6.1	10.0	12.4	6.7	7.1	6.6	4.9	5.5	4.7	5.2	3.9	5.7	16.0	
3	3.4	6.0	14.2	13.2	7.3	4.7	4.4	4.5	5.9	5.2	3.5	2.2	5.2	19.1	
4	3.5	7.9	11.0	11.1	9.2	4.9	5.2	5.0	5.8	6.0	4.0	3.3	5.6	17.1	
5	3.6	8.0	10.8	17.5	4.7	5.5	4.3	4.4	4.8	5.4	5.0	3.4	5.6	16.9	
6	4.6	5.2	10.2	8.5	7.4	5.1	5.8	6.2	6.5	5.2	4.8	4.2	6.0	19.8	
7	2.9	6.4	13.6	12.2	8.2	5.2	6.2	5.2	6.3	5.2	4.2	3.7	4.5	16.0	
8	1.3	4.4	14.8	19.4	7.4	5.0	5.6	4.8	4.7	5.2	4.1	3.2	5.0	14.6	
9	3.4	4.6	13.6	10.9	7.1	5.1	4.2	5.5	6.0	5.6	5.4	3.8	5.6	18.8	
10	1.4	3.5	14.0	18.8	6.8	4.6	3.3	4.8	5.0	6.2	4.9	2.8	5.1	18.4	
11	2.3	7.4	6.3	12.0	3.4	5.4	6.9	6.1	4.5	6.6	5.5	4.1	6.1	22.9	
12	3.7	5.6	14.5	16.8	9.7	4.8	3.7	3.8	5.3	5.3	6.3	5.8	8.1	12.1	
13	.9	3.0	6.9	16.7	7.5	6.4	4.8	6.5	5.8	6.6	5.8	4.2	5.6	19.0	
14	3.2	5.1	10.0	16.5	7.2	6.5	5.1	5.3	6.3	5.1	4.2	3.4	5.6	16.1	
16	3.0	6.9	13.4	12.0	7.6	6.6	5.6	5.1	6.0	5.2	4.3	3.3	4.4	16.2	

INCLINED-RETORT TAR CREOSOTES.

17	5.9	5.9	9.9	13.1	6.5	5.3	5.4	5.7	6.7	4.3	4.9	4.3	5.3	16.6
18	1.3	5.6	22.9	12.4	7.2	4.8	4.5	5.4	5.8	4.5	3.9	2.5	4.2	14.5
19	1.3	2.1	3.9	5.1	3.6	3.4	2.9	3.2	4.8	6.0	4.6	4.6	8.3	46.2
20	1.6	2.9	8.6	11.9	4.5	6.8	5.8	4.8	9.8	7.5	4.4	5.0	6.2	19.7
21	4.2	5.8	7.0	9.0	4.4	7.2	6.3	7.0	5.2	8.8	5.2	4.6	7.2	18.1
22	1.4	3.5	14.5	14.4	8.4	6.7	4.0	5.4	6.3	5.5	4.2	3.5	4.8	16.8

VERTICAL-RETORT TAR CREOSOTES.

23	8.7	7.9	11.2	10.1	5.7	5.3	6.8	6.0	6.1	4.9	4.3	3.6	5.4	12.8
----	-----	-----	------	------	-----	-----	-----	-----	-----	-----	-----	-----	-----	------

OTTO TAR CREOSOTES.

24	.2	1.0	12.6	8.0	3.5	2.1	2.0	2.3	5.0	6.6	3.9	5.7	9.9	36.2
25	3.6	10.0	12.6	8.8	11.6	4.8	5.8	4.6	3.9	6.0	4.4	3.5	3.7	16.2
26	1.8	4.7	25.2	13.7	5.2	4.3	3.7	3.4	3.9	5.7	4.4	3.0	3.6	16.0
27	.5	3.5	20.7	12.4	11.7	5.6	4.0	3.9	4.2	4.6	4.6	3.7	3.2	16.2

SEMET-SOLVAY TAR CREOSOTES.

29	6.8	8.8	13.0	10.0	4.2	7.5	3.9	4.1	5.4	4.7	5.0	1.1	9.1	16.3
30	3.1	5.9	9.9	8.6	8.2	5.5	5.3	6.2	6.4	5.7	6.2	4.1	5.3	19.1
31	2.8	2.7	15.3	13.1	6.6	3.7	3.4	4.9	4.4	7.9	4.8	5.2	5.2	20.0
32	1.8	1.8	10.1	8.3	6.8	3.3	4.2	3.6	6.6	8.0	5.2	4.8	7.2	27.9
33	4.8	4.8	13.0	16.7	7.7	5.8	5.2	5.2	5.5	6.0	3.0	2.7	5.2	17.0
34														

KOPPERS TAR CREOSOTES.

35	.3	1.1	33.4	10.1	2.4	2.5	2.2	3.1	5.1	6.2	4.7	2.5	5.3	20.6
----	----	-----	------	------	-----	-----	-----	-----	-----	-----	-----	-----	-----	------

¹ No creosote could be produced. Too much free carbon and nothing else but water.

TABLE 40.—Indices of refraction at 60° C. of fractions of coal-tar creosotes.

HORIZONTAL-RETORT TAR CREOSOTES.

Tar No.	Fraction limits.								
	235 to 245° C.	245 to 255° C.	255 to 265° C.	265 to 275° C.	275 to 285° C.	285 to 295° C.	295 to 305° C.	305 to 315° C.	315 to 330° C.
	No.	No.	No.	No.	No.	No.	No.	No.	
1	1.5944	1.5963	1.5980	1.6020	1.6070	1.6142	1.6213	1.6283	N. L. ¹
2	1.5892	1.5933	1.5964	1.5995	1.6048	1.6108	1.6173	1.6250	N. L.
3	1.5935	1.5937	1.5953	1.5978	1.6027	1.6085	1.6155	1.6228	N. L.
4	1.5965	1.5923	1.5938	1.5969	1.6012	1.6080	1.6150	1.6223	N. L.
5	1.5923	1.5924	1.5945	1.5988	1.6035	1.6092	1.6190	1.6263	N. L.
6	1.5895	1.5919	1.5946	1.5975	1.6022	1.6093	1.6157	1.6237	N. L.
7	1.5930	1.5936	1.5948	1.5979	1.6028	1.6090	1.6163	1.6230	N. L.
8	1.5950	1.5952	1.5958	1.5985	1.6041	1.6118	1.6195	1.6269	N. L.
9	1.5931	1.5945	1.5960	1.5995	1.6050	1.6108	1.6178	1.6258	N. L.
10									
11	1.5971	1.5873	1.5984	1.6003	1.6050	1.6122	1.6182	1.6257	N. L.
12	1.5813	1.5892	1.5913	1.5940	1.5983	1.6057	1.6108	1.6166	N. L.
13	1.5882	1.5898	1.5907	1.5940	1.5985	1.6048	1.6120		N. L.
14	1.5920	1.5930	1.5942	1.5965	1.6010	1.6060	1.6140	1.6205	N. L.
15	1.5869	1.5900	1.5918	1.5947	1.5997	1.6046	1.6118	1.6197	N. L.
16	1.5915	1.5923	1.5932	1.5963	1.6013	1.6075	1.6100	N. L.	N. L.

INCLINED-RETORT TAR CREOSOTES.

17	1.5792	1.5795	1.5802	1.5822	1.5862	1.5922	1.5988	1.6052	N. L.
18	1.5843	1.5821	1.5816	1.5836	1.5875	1.5943	1.6010	1.6078	N. L.
19	1.5800	1.5824	1.5840	1.5868	1.5919	1.5980	1.6040	1.6113	N. L.
20	1.5830	1.5852	1.5868	1.5892	1.5925	1.5993	1.6023	1.6083	N. L.
21	1.5745	1.5758	1.5773	1.5796	1.5890	1.5888	1.5942	1.5988	N. L.
22	1.5925	1.5926	1.5931	1.5963	1.6003	1.6078	1.6147	1.6230	N. L.

VERTICAL-RETORT TAR CREOSOTES.

23	1.5716	1.5754	1.5776	1.5810	1.5843	1.5904	1.5971	1.6047	N. L.
----	--------	--------	--------	--------	--------	--------	--------	--------	-------

OTTO TAR CREOSOTES.

24	1.6021	1.6028	1.6041	1.6071	1.6132	1.6208	1.6273	N. L.	N. L.
25	1.5936	1.5949	1.5970	1.5994	1.6032	1.6100	1.6165	1.6245	N. L.
26	1.5998	1.6003	1.6018	1.6042	1.6105	1.6160	1.6229	N. L.	N. L.
27	1.6004	1.6015	1.6021	1.6051	1.6095	1.6160	1.6230	N. L.	N. L.
28									

SEMET-SOLVAY TAR CREOSOTES.

29	1.5915	1.5928	1.5937	1.5968	1.6011	1.6073	1.6122	1.6192	N. L.
30	1.5918	1.5933	1.5950	1.5983	1.6031	1.6098	1.6170	1.6243	N. L.
31	1.5979	1.5983	1.5993	1.6532	1.6090	1.6170	1.6232	N. L.	N. L.
32	1.5996	1.6000	1.6018	1.6046	1.6103	1.6170	1.6240	N. L.	N. L.
33	1.5880	1.5878	1.5883	1.5901	1.5941	1.6012	1.6080	1.6183	N. L.
34									

KOPPERS TAR CREOSOTES.

35	1.6031	1.6050	1.6071	1.6122	1.6182	1.6251	1.6322	N. L.	N. L.
----	--------	--------	--------	--------	--------	--------	--------	-------	-------

¹ Not liquid at 60° C.

TABLE 41.—*Specific gravities of fractions of coal-tar creosotes* (*Sp. Gr.* $\frac{60}{60}$).

HORIZONTAL-RETORT TAR CREOSOTES.

Tar No.	Fraction limits.								
	235 to 245° C.	245 to 255° C.	255 to 265° C.	265 to 275° C.	275 to 285° C.	285 to 295° C.	295 to 305° C.	305 to 315° C.	315 to 330° C.
	<i>Sp. gr.</i>	<i>Sp. gr.</i>	<i>Sp. gr.</i>	<i>Sp. gr.</i>	<i>Sp. gr.</i>	<i>Sp. gr.</i>	<i>Sp. gr.</i>	<i>Sp. gr.</i>	
1.....	1.018	1.022	1.029	1.039	1.050	1.065	1.077	1.086	N. L. ¹
2.....	1.021	1.025	1.033	1.037	1.050	1.067	1.077	1.084	N. L.
3.....	1.015	1.020	1.026	1.034	1.045	1.058	1.073	1.084	N. L.
4.....	1.017	1.021	1.027	1.036	1.046	1.060	1.068	1.084	N. L.
5.....	1.014	1.018	1.029	1.037	1.048	1.060	1.072	1.084	N. L.
6.....	1.017	1.022	1.027	1.035	1.047	1.061	1.072	1.080	N. L.
7.....	1.016	1.021	1.028	1.036	1.047	1.062	1.073	1.079	N. L.
8.....	1.019	1.020	1.027	1.036	1.044	1.063	1.077	1.084	N. L.
9.....	1.017	1.022	1.027	1.040	1.049	1.063	1.073	1.084	N. L.
10.....	1.020	1.023	1.032	1.039	1.049	1.066	1.075	1.084	N. L.
11.....	1.012	1.015	1.026	1.032	1.041	1.053	1.062	1.067	N. L.
12.....	1.018	1.022	1.032	1.043	1.043	1.056	1.068	1.073	N. L.
13.....	1.019	1.024	1.028	1.034	1.045	1.054	1.065	1.073	N. L.
14.....	1.017	1.021	1.025	1.033	1.044	1.052	1.064	1.073	N. L.
15.....	1.019	1.023	1.028	1.035	1.048	1.062	1.072	1.084	N. L.

INCLINED-RETORT TAR CREOSOTES.

17.....	1.007	1.009	1.015	1.020	1.029	1.038	1.047	1.054	N. L.
18.....	1.006	1.007	1.009	1.016	1.027	1.040	1.050	1.060	N. L.
19.....	1.008	1.005	1.026	1.034	1.044	1.053	1.060	1.066	N. L.
20.....	1.010	1.013	1.018	1.024	1.032	1.041	1.050	1.056	N. L.
21.....	1.005	1.009	1.013	1.020	1.028	1.035	1.043	1.049	N. L.
22.....	1.017	1.022	1.025	1.035	1.045	1.058	1.067	1.073	N. L.

VERTICAL-RETORT TAR CREOSOTES.

23.....	1.003	1.007	1.013	1.020	1.032	1.038	1.049	1.054	N. L.
---------	-------	-------	-------	-------	-------	-------	-------	-------	-------

OTTO TAR CREOSOTES.

24.....	1.020	1.040	1.055	1.074	1.077	N. L.	N. L.
25.....	1.017	1.020	1.031	1.040	1.061	1.077	N. L.
26.....	1.020	1.025	1.035	1.053	1.067	1.075	N. L.
27.....	1.025	1.030	1.039	1.052	1.062	1.075	N. L.
28.....							N. L.

SEMET-SOLVAY TAR CREOSOTES.

29.....	1.013	1.024	1.033	1.046	1.060	1.075	1.078	N. L.
30.....	1.013	1.017	1.021	1.031	1.043	1.057	1.070	N. L.
31.....	1.014	1.018	1.022	1.037	1.048	1.064	1.076	N. L.
32.....	1.020	1.022	1.039	1.039	1.054	1.069	1.083	N. L.
33.....	1.010	1.013	1.017	1.024	1.033	1.048	1.061	N. L.
34.....								N. L.

KOPPERS TAR CREOSOTES.

35.....	1.027		1.041	1.065	1.082	1.089	N. L.	N. L.
---------	-------	--	-------	-------	-------	-------	-------	-------

¹ Not liquid at 60° C.

TABLE 42.—*Sulphonation residues of fractions of coal-tar creosotes.*

HORIZONTAL-RETORT TAR CREOSOTES.

Tar No.	Fraction limits.										
	215 to 225° C.	225 to 235° C.	235 to 245° C.	245 to 255° C.	255 to 265° C.	265 to 275° C.	275 to 285° C.	285 to 295° C.	295 to 305° C.	305 to 315° C.	315 to 330° C.
1	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
2				<i>tr.</i>	<i>tr.</i>	<i>tr.</i>	<i>tr.</i>	<i>tr.</i>	<i>tr.</i>	<i>tr.</i>	<i>tr.</i>
3	<i>tr.</i>	0.1	0.2	0.4	0.6	0.8	0.8	0.6	0.8		0.3
4	0.1	.1	.4	.6	1.0	1.2	1.4	1.6	1.4	1.2	<i>tr.</i>
5	.2	.2	.4	.6	.8	.8	.8	.4	.4	.2	.7
6	<i>tr.</i>	<i>tr.</i>	.1	.3	.5	.8	.7	.6	.9	.9	.1
7	<i>tr.</i>	<i>tr.</i>	.1	.4	.6	.8	.7	.8	.6	.4	.4
8	<i>tr.</i>	<i>tr.</i>	.1	.4	.4	.8	1.0	1.0	0.8		.2
9	<i>tr.</i>	<i>tr.</i>	.1	.2	.4	.6	.7	.7	.2	.6	.6
10											
11	<i>tr.</i>	<i>tr.</i>	.1	.3	.4	.6	.8	.8	.2	.4	.4
12	.2	.2	.2	.7	1.0	1.2	1.6	1.8	2.0	2.0	2.0
13	.4	.8	1.2	1.6	2.0	2.0	3.0	2.4	1.8		.6
14	.2	.2	.3	.8	1.2	1.4	1.8	1.8	2.2	1.2	2.2
15	.2	.4	.4	.8	1.0	1.4	1.4	1.4	1.0	1.2	.6
16	.1	.1	.2	.3	.4	.6	.7	.7	.4	.4	.8

INCLINED-RETORT TAR CREOSOTES.

17	1.8	2.2	3.4	4.4	6.4	6.8	7.2	4.8	2.0	2.0	2.0
18	1.2	1.6	2.8	4.4	6.2	6.4	7.0	7.6	4.6	4.0	3.2
19	1.2	1.2	1.2	2.6		2.4	5.0	3.6	4.2	3.0	6.0
20	1.8	1.0	1.2	1.6	2.2	2.8	3.0	4.0	4.6	4.8	5.8
21	1.8	2.2	2.8	3.6	4.6	5.2	5.8	6.8	7.6	8.0	8.2
22	.6	.4	.6	1.0	1.2	2.0	2.2	2.8	1.6	1.6	1.8

VERTICAL-RETORT TAR CREOSOTES.

23	1.2	3.6	4.0	5.0	5.2	5.6	6.4	5.4	5.2	4.6
----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

OTTO TAR CREOSOTES.

[illegible]

SEMET-SOLVAY TAR CREOSOTES.

[illegible]

KOPPERS TAR CREOSOTES.

[illegible]

TABLE 43.—*Distillation of water-gas-tar creosotes (Hempel flask).*

Tar No.	Fraction limits.													Res.
	Up to 205° C.	205 to 215° C.	215 to 225° C.	225 to 235° C.	235 to 245° C.	245 to 255° C.	255 to 265° C.	265 to 275° C.	275 to 285° C.	285 to 295° C.	295 to 305° C.	305 to 315° C.	330° C.	
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
37	2.8	3.0	8.6	15.5	5.2	11.2	9.6	6.5	5.0	4.9	3.2	3.5	4.4	16.4
38	3.3	2.4	11.0	15.2	9.1	6.4	8.4	6.7	6.8	4.5	3.8	3.3	3.8	14.9
39	2.4	3.7	12.8	13.4	11.5	6.1	6.9	5.4	5.8	6.4	3.4	3.8	6.1	13.5
40	2.2	2.0	5.4	12.0	14.3	5.4	11.1	9.7	7.3	6.0	7.1	4.3	5.5	8.7
41	3.2	2.7	5.1	8.4	7.9	7.2	8.6	7.8	6.3	7.2	5.7	5.5	5.2	18.9
42	2.4	2.4	17.8	14.2	6.7	3.6	3.6	3.0	2.9	3.3	3.6	1.8	7.1	27.1
43	3.0	3.2	8.0	19.9	8.6	7.8	6.2	3.7	6.2	5.2	3.1	3.7	5.6	15.9
44	2.2	4.3	14.8	14.6	7.8	3.9	3.6	5.9	5.1	5.4	3.8	3.9	5.6	18.9
45	2.4	2.2	14.6	11.8	10.3	2.7	6.6	6.6	4.4	7.2	4.7	3.7	6.2	16.2
46	2.9	2.8	10.4	13.8	9.5	7.0	6.8	5.1	4.8	4.0	2.3	3.6	6.0	21.2
47	1.9	3.5	9.2	12.5	12.6	5.0	9.2	8.5	5.0	5.6	4.0	4.0	6.1	12.6
48	2.2	2.9	13.0	11.1	8.7	6.9	5.6	4.3	6.0	5.1	7.6	4.4	6.4	16.1
49	2.5	5.2	13.2	13.8	10.8	7.7	2.6	3.6	2.1	1.9	1.4	1.7	5.0	26.6
50	2.6	2.4	16.2	21.6	7.0	5.6	4.7	3.6	5.5	4.6	2.9	3.8	4.7	14.4
51	3.3	2.8	7.4	14.0	12.5	7.4	5.9	8.2	6.7	5.2	2.7	3.2	5.9	14.3
52	7.6	5.0	5.3	6.9	11.8	9.0	8.5	6.7	7.8	6.3	4.4	2.5	4.9	12.9
53	1.2	1.2	17.0	16.9	7.1	4.4	3.1	5.4	6.0	4.7	4.0	3.6	5.8	19.6
54	1.1	1.6	17.7	15.8	5.6	4.0	3.2	3.3	5.0	5.0	4.3	4.8	6.6	21.7

TABLE 44.—*Indices of refraction of fractions of water-gas-tar creosotes.*

Tar No.	Fraction limits.								
	235 to 245° C.	245 to 255° C.	255 to 265° C.	265 to 275° C.	275 to 285° C.	285 to 295° C.	295 to 305° C.	305 to 315° C.	315 to 330° C.
	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>	<i>No.</i>
37	1.5728	1.5728	1.5734	1.5742	1.5748	1.5780	1.5818	1.5880	1.6032
38	1.5875	1.5853	1.5842	1.5828	1.5833	1.5861	1.5893	1.5990	N. L. ¹
39	1.5873	1.5854	1.5831	1.5828	1.5838	1.5870	1.5912	1.5980	N. L.
40	1.5798	1.5812	1.5817	1.5811	1.5817	1.5814	1.5832	1.5872	1.5988
41	1.5574	1.5612	1.5625	1.5636	1.5635	1.5645	1.5662	1.5696	1.5812
42	1.5931	1.5915	1.5904	1.5891	1.5901	1.5923	1.5954	1.5996	1.6097
43	1.5922	1.5928	1.5932	1.5935	1.5968	1.6007	1.6068	1.6134	1.6282
44	1.5938	1.5925	1.5931	1.5952	1.5973	1.6022	1.6070	1.6160	N. L.
45	1.5848	1.5808	1.5786	1.5778	1.5780	1.5804	1.5827	1.5890	1.5985
46	1.5886	1.5884	1.5880	1.5875	1.5878	1.5902	1.5940	1.5990	1.6108
47	1.5760	1.5775	1.5778	1.5786	1.5798	1.5819	1.5858	1.5915	1.5988
48	1.5790	1.5772	1.5742	1.5720	1.5715	1.5722	1.5732	1.5782	1.5868
49	1.5820	1.5770	1.5731	1.5735	1.5753	1.5753	1.5826	1.5944	N. L.
50	1.5982	1.5982	1.5985	1.6006	1.6052	1.6106	1.6185	1.6264	N. L.
51	1.5868	1.5864	1.5866	1.5878	1.5898	1.5941	1.5996	1.6080	1.6240
52	1.5640	1.5698	1.5739	1.5770	1.5792	1.5825	1.5878	1.5948	1.6060
53	1.5972	1.5960	1.5974	1.6025	1.6064	1.6142	1.6212	1.6295	N. L.
54	1.5975	1.5980	1.5996	1.6019	1.6082	1.6148	1.6218	1.6303	N. L.

¹ Not liquid at 60° C.

TABLE 45.—*Specific gravities of fractions of water-gas tar creosotes.*

	Distillation limits.								
Tar No.	235 to 245° C.	245 to 255° C.	255 to 265° C.	265 to 275° C.	275 to 285° C.	285 to 295° C.	295 to 305° C.	305 to 315° C.	315 to 330° C.
	<i>Sp. gr.</i>	<i>Sp. gr.</i>	<i>Sp. gr.</i>	<i>Sp. gr.</i>	<i>Sp. gr.</i>	<i>Sp. gr.</i>	<i>Sp. gr.</i>	<i>Sp. gr.</i>	<i>Sp. gr.</i>
37	0.986	0.986	0.986	0.989	0.996	1.009	1.009		
38	.997	.996	1.001	1.000	1.006	1.019	-----	-----	N. L. ¹
39	1.002	1.001	.998	.992	1.001	1.015	1.018		N. L.
40	.987	.988	.989	.989	.989	.992	1.000	1.015	
41	.960	.962	.964	.966	.967	.972	.975	.984	0.998
42	1.006	1.003		1.006		1.021	-----	-----	1.041
43	1.000	.999	1.003	-----	1.014	1.021	1.041		1.063
44	1.006	1.007		1.013	1.024	1.029	1.044		N. L.
45	.996	-----	.994	.995	1.000	1.007	1.015		N. L.
46	.998	.997	.997	1.000	1.003	1.015	-----	-----	1.033
47	.987	.987	.993	.996	.998	1.002	1.016		1.039
48	.992	.993	.986	.984	.986	.989	.992	-----	1.009
49	.995	.992	.993	-----	-----	1.005	-----	-----	N. L.
50	1.008	1.009	1.014	1.029		1.039	1.071		N. L.
51	.996	.996	.998	1.004	1.009	1.020	1.040		1.066
52	.971	.979	.984	.989	.995	1.000	1.009	-----	1.034
53	1.010	1.015		1.027	1.041	1.068	-----	-----	N. L.
54	1.009	1.018		1.032		1.047	1.060	-----	N. L.

¹ Not liquid at 60° C.TABLE 46.—*Sulphonation residues of fractions of water-gas tar creosotes.*

	Fraction limits.											
Tar No.	205 to 225° C.	225 to 235° C.	235 to 245° C.	245 to 255° C.	255 to 265° C.	265 to 275° C.	275 to 285° C.	285 to 295° C.	295 to 305° C.	305 to 315° C.	315 to 330° C.	
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	
37	8.6	8.4	8.0	8.2	8.8	10.0		10.8		11.2	8.6	
38	1.4	1.6	2.0	4.2	4.4	6.0	7.6	-----		7.8	8.0	
39	1.0	.8	2.4	3.2	4.4	5.4	7.0	7.6		8.4	7.4	
40	1.6	1.4	2.4	3.2	4.2	4.8	6.0	7.6		8.8	7.4	
41	10.0	9.8	10.0	11.0	12.2	12.8	13.6	14.4	16.4	17.2	16.4	
42	Tr.	.4	1.2	2.4		5.2		7.0			1.2	
43	Tr.	.2	.3	.4	.6	1.0	1.6	2.0		1.6	1.4	
44	.4	.4	.6	1.4	-----	2.4	2.8	3.0		3.0	2.8	
45	2.0	2.0	3.4	4.0	6.0	8.1	9.4	10.0		10.6	12.2	
46	Tr.	.4	.4	1.4	1.8	2.4	3.2	4.0		3.6	-----	
47	3.8	5.0	4.8	5.4	5.6	6.6	7.0	8.0		9.0	8.4	
48	2.8	3.2	5.2	7.4	8.8	10.8	13.6	15.8	16.8	17.6	15.0	
49	Tr.	Tr.	.2	.8	2.4		-----	4.4			4.2	
50	0	0	0	0	0	0	0	0	0	0	0	
51	1.2	1.4	2.0	2.2	2.4	2.6	2.8	2.8		2.4	1.6	
52	9.2	9.4	8.4	8.4	6.6	4.6	6.4	7.0	7.4	6.0	4.4	
53	0	0	0	0	0	0	0	Tr.	0	0	0	
54	0	0	0	0	0	0	0	Tr.	0	0	0	

BIBLIOGRAPHY.

1. HELPHENSTINE, R. K., Jr. Consumption of Wood Preservatives. (In Proceedings of American Wood Preservers' Association, 1919, p. 274.)
2. LEWES, V. B. Carbonization of Coal.
3. HUBBARD, P. Coke-oven Tars of the United States (U. S. Department of Agriculture, Office of Public Roads Circular No. 99.)
4. FULWEILER, W. H. Water-gas. (In Rogers and Auber's Industrial Chemistry, chap. XXI, p. 447.)
5. PARKER, E. W. Production of Gas, Coke, Tar, and Ammonia, 1908. (In Mineral Resources of the U. S., 1908, U. S. Geological Survey.)
6. PARKER, E. W. Production of Gas, Coke, Tar, and Ammonia, 1912. (In Mineral Resources of the U. S., 1912, U. S. Geological Survey.)
7. U. S. GEOLOGICAL SURVEY. Artificial Gas and By-products in 1917. (Press bulletin.)
8. Private communications from the Geological Survey.
9. PARKER, E. W. Production of Gas, Coke, Tar, and Ammonia, 1905. (In Mineral Resources of the U. S., 1905, U. S. Geological Survey.)
10. LUNGE, GEORGE. Coal Tar and Ammonia. (5th ed., N. Y., Van Nostrand, 1916.)
11. WARNES, A. R. Distillation of Coal Tar. (N. Y., Van Nostrand, 1914.)
12. DEAN, A. L., and BATEMAN, E. Analysis and Grading of Coal-tar Creosote. (U. S. Forest Service Circular No. 112).
13. THEISEN-SCHEEL and DIESSELHORST. (Van Nostrand Chemical Annual, 1909.)
14. BERRY, O. C. Tar-forming Temperatures of American Coals. (University of Wisconsin Bulletin No. 635.)
15. American Society for Testing Materials, Proceedings, 1917, p. 621.
16. WEISS, H. F. Tests to Determine the Commercial Value of Wood Preservatives. (In Proceedings of Eighth International Congress of Applied Chemistry, 1912.)
17. BOND, F. M. The Effect upon Absorption and Penetration of Mixing Tar with Creosote. (In Proceedings of American Wood Preservers' Association, 1913, pp. 216-274.)
18. TEESDALE, C. H., and MACLEAN, J. D. Tests of the Absorption and Penetration of Coal Tar and Creosote in Longleaf Pine. (U. S. Department of Agriculture Bulletin No. 607.)
19. ALLEMAN, G. Quantity and Quality of Creosote in Well-preserved Timbers. (U. S. Forest Service Circular No. 88.)
20. VON SCHRENK, H., and others. Changes which Take Place in Coal-Tar Creosote during Exposure. (In Proceedings of American Railway Engineering Association, 1908, pp. 738-764).
21. BATEMAN, E. Quantity and Quality of Creosote Found in Two Treated Piles after Long Service. (U. S. Forest Service Circular No. 199.)
22. RIDGWAY, F. B. Report on Creosoted Piling in Galveston Bay Bridge on the Santa Fe Railroad. (In Proceedings of American Wood Preservers' Association, 1914, pp. 194-215.)
23. RHODES, F. L., and HOSFORD, R. F. Recent Results Obtained from the Preservative Treatment of Telephone Poles. (In Proceedings of American Institute of Electrical Engineers, 1915.)

24. CABOT, S. Value of Higher Phenols in Wood-preservative Oils; Apparent Disappearance of the Higher-Boiling Phenols in Creosoted Wood. (In *Journal of Industrial and Engineering Chemistry*, 1912.)
25. VON SCHRENK, H., and KAMMERER, A. L. The Use of Refined Coal-tar in the Creosoting Industry. (In *Proceedings of American Railway Engineering Association*, 1914, pp. 635-681.)
26. BATEMAN, E., and TOWN, G. G. Loss by Evaporation of Creosote from Open-tank Treatments. (In *Proceedings of American Wood Preservers' Association*, 1920.)
27. BATEMAN, E. What Light Oils Have Done in Wood Preservation. (In *Proceedings of American Wood Preservers' Association*, 1920.)
28. CHAPMAN, C. M. A Fungus-bed Test for Wood Preservatives. (In *Proceedings of American Society for Testing Materials*, 1915.)
29. HUMPHREY, C. J., and FLEMING, R. M. Toxicity of Various Wood Preservatives. (In *Journal of Industrial and Engineering Chemistry*, 1914-1915.)
——— Tests of Wood Preservatives. (U. S. Department of Agriculture Bulletin No. 145.)
30. DEAN, A. L., and DOWNES, C. R. Antiseptic Properties of Wood-preserving Oils. (In *Proceedings of Eighth International Congress of Applied Chemistry*, 1912.)
31. WEISS, J. M. The Action of Oils and Tar in Preventing Mould Growth; The Antiseptic Effect of Creosote Oil and Other Wood-preserving Materials. (In *Journal of the Society of Chemical Industry*, 1911, vol. 30, No. 4, p. 190.)
32. RUSSELL, E. J., and PENDLETON, W. The Action of Antiseptics in Increasing the Growth of Crops in Soils. (In *Journal of the Society of Chemical Industry*, 1913, vol. 32, No. 24, pp. 1137, 1138.)
33. CHARITSCHKOW, K. W. Antiseptic Properties of Creosote. (In *Journal of the Russian Chemical Society*, 1912.)
34. HUNTLEY, H. W. Identification and Toxic Action of Some Compounds in Coal-tar Creosote. (Unpublished Manuscript at U. S. Forest Products Laboratory, 1915.)
35. TRILLAT, A. Antiseptic and Medicinal Properties Derived from Coal-tar. (In *Moniteur Scientific*, 1892.)
36. ADIASIEWITSCH, A. W. Treatment of Wood with Antiseptics Prepared from Coal Tar. (Abstract, *Journal of the Society of Chemical Industry*, 1897.)
37. BOKORNY, Efficiency of Phenol as a Disinfectant Compared with Other Poison. (*Chemiker Zeitung*, 1906.)
38. SCHNEIDER, H. Disinfectants from Naphthols. (*Chemiker Cent.*, 1906.)
39. MORGAN, G. F., and COOPER, E. A. Germicidal Power of Organic Hydroxy Compounds and Amines. (In *Proceedings of Eighth International Congress of Applied Chemistry*, 1912.)
40. SHACKELL, L. F. Comparative Toxicity of Coal-tar Creosote and Creosote Distillates for the Marine Wood Borer, *Xylotrya*. (In *Proceedings of American Wood Preservers' Association*, 1915, pp. 233-252.)
41. BATEMAN, E. A Theory on the Mechanism of Protection by Wood Preservatives. (In *Proceedings of American Wood Preservers' Association*, 1920.)
42. FREDENDOLL, P. F. Evaporation of Creosote and Crude Oils. (In *Proceedings of American Wood Preservers' Association*, 1912, pp. 107-117.)
43. BATEMAN, E. The Relation Between Viscosity and Penetrance of Creosote into Wood. (In *Chemical and Metallurgical Engineering*, 1920.)
44. WEISS, J. M. Free Carbon: Its Nature and Determination in Tar Products. (In *Journal of Industrial and Engineering Chemistry*, 1914.)

45. MONROE, G. S., and BRODERSON, H. J. Some Effects of Certain Solvents on Tars in Free-carbon Determination. (In Journal of Industrial and Engineering Chemistry, 1918.)
46. DAVIS, T. H. The Examination of Creosote. (In Oil, Paint, and Drug Reporter, 1909.)
47. CLOUKEY, H. The Application of the Davis Spot Test in the Preliminary Examination of Creosote. (In Journal of Industrial and Engineering Chemistry, 1915.)
48. National Electric Light Association, Proceedings, 1911.
49. BATEMAN, E. Discussion on Paving-block Specifications. (In Proceedings of American Wood Preservers' Association, 1917.)
50. DEAN, A. L., and BATEMAN, E. The Fractional Distillation of Coal-tar Creosote, (U. S. Forest Service Circular No. 80.)
51. National Electric Light Association, Proceedings, 1911.
52. American Railway Engineering Association, Proceedings, 1913.
53. MANN, J. C. The Testing of Coal-tar Creosote. (In Journal of the Society of Chemical Industry, 1910.)
54. American Railway Engineering Association, Proceedings, 1908.
55. CHAPIN, R. M. The Analysis of Coal-tar Creosote and Cresylic Acid Sheep Dip. (U. S. Bureau of Animal Industry Bulletin 107.)
56. FULWEILER, W. H. Report on Water Gas Tar. (In Proceedings of American Wood Preservers' Association, 1921.)
57. MATOS, F. D. Long Wharf Piles. (In Proceedings of American Wood Preservers' Association, 1920.)

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
20 CENTS PER COPY



UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1037

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief.



Washington, D. C.

PROFESSIONAL PAPER

August 19, 1922

THE CONTROL OF SAP-STAIN, MOLD, AND INCIP- IENT DECAY IN GREEN WOOD, WITH SPECIAL REFERENCE TO VEHICLE STOCK.¹

By NATHANIEL O. HOWARD, *Pathologist, Office of Investigations in Forest Pathology.*

(In cooperation with the Forest Products Laboratory of the United States Forest Service, Madison, Wis.)

CONTENTS.

	Page.		Page.
Introduction	1	Durability of stained or molded	
Sap-stain	3	wood	17
Other fungous organisms causing		Losses due to sap-stain or mold	18
surface discolorations in green tim-		Control measures	21
ber	12	Summary	50
Factors which favor the growth of		Literature cited	52
sap-stain and mold fungi	14		

INTRODUCTION.

During periods of transit and storage, previous to its ultimate manufacture, green timber containing a high percentage of sapwood often suffers considerable damage. This is particularly true during the late spring and summer months when deterioration brought about mainly through a discoloration of the sapwood, known as sap-stain, sometimes necessitates degrading on a large scale. This staining of timber has occasioned severe losses in Europe as well as in the United States, and many expensive investigations have been made to determine the nature of the stain and to discover a satisfactory remedy.

¹ The writer wishes to acknowledge his indebtedness to Mr. C. J. Humphrey, in charge of the Laboratory of Forest Pathology, Bureau of Plant Industry, in cooperation with the Forest Products Laboratory, Madison, Wis., for facilities and for advice in outlining the work; to Dr. Charles Thom and Miss Margaret B. Church, of the Bureau of Chemistry, for the identification of mold fungi; to Mr. H. D. Tiemann, physicist and specialist in kiln drying, Forest Products Laboratory, Madison, Wis., for the loan of photographs; to Mr. Joseph Ashcroft, of Poplar Bluff, Mo., for cooperation in the experimental dipping of spokes; and to all others who, by information, suggestion, or criticism, have contributed to the preparation of the manuscript of this bulletin.

The molding of green timber has frequently been confused with sap-stain as well as with incipient decay. However, in so far as the production of permanent stain or the effect upon the durability of the wood is concerned, molding is of comparatively little importance. Incipient decay caused by true wood-destroying fungi, on the other hand, is of great importance.

Early in the year 1918 the attention of the Office of Investigations in Forest Pathology was called to staining and molding occurring in green raw material by the wood-stock committee representing the National Implement and Vehicle Association and other vehicle and vehicle parts manufacturers through the Forest Products Laboratory of the United States Forest Service, Madison, Wis. The present investigation arose in connection with raw hardwood stock used in the manufacture of escort wagons and artillery carriages. A large quantity of this material was at that time being sawed or turned, largely from green instead of seasoned stock and shipped green from the saw. In some cases it was found necessary to cull severely such stock at destination, owing to the presence of mold, stain, or incipient decay which had developed during transit and while in storage. In cooperation with the Forest Products Laboratory and the wood-stock committee, a questionnaire² was sent to a number of the contractors for Army vehicles and parts and to producers of wood stock. Personal investigations were also made of the conditions existing at 45 mills and factories engaged in the sawing of timber, dimension stock, and veneer, or in the manufacture of airplanes, furniture, flooring, handles, vehicles, and vehicle parts. Most of these mills were located in the central and southern portions of the United States and were directly concerned in the production of war material. The object of both questionnaire and personal investigations was to gain information concerning the general sanitary conditions existing in the woods, railway cars, sheds, warehouses, and kilns; the details of manufacture of many vehicle parts; the extent of deterioration occurring in green raw material; the financial losses occasioned thereby; and, particularly, any practical methods of handling green wood stock that would prevent the development of stain and mold therein.

The investigations showed that many of the firms had experienced considerable pecuniary losses, which were due to the necessity of using a high percentage of green stock; to a shortage of cars, resulting in the congestion of material in the woods and railroad

² National Implement and Vehicle Association and other Vehicle and Vehicle Parts Manufacturers. Information Division of the Wagon and Vehicle Committee and the Wheel Manufacturers' War Service Committee. Wood Stock Committee. Sap-stain and mold in green lumber. Nat. Implement and Vehicle Assoc., etc., Bul. 24, 2 p., 1 fig. 1918. A. E. Thielens, chairman. Multigraphed.

yards; to lack of time for the proper air seasoning or kiln drying preparatory to shipment; and, finally, in some cases to a failure to understand the conditions necessary to safeguard the stock while in storage or in transit. Many of these losses due to emergency will be considerably reduced upon return to normal conditions.

Some manufacturers consider it important that, in order to overcome losses due to checking, certain kinds of stock produced at many of the smaller mills be shipped to them in a green rather than in a partly seasoned condition. They claim that these mills, not being equipped for the proper drying of stock preliminary to shipment, make it necessary for the manufacturer to insist that material from such sources be shipped in a green condition to the factory, where suitable means for storage and drying are maintained. Close attention must be paid to the handling of this material in transit or in storage if deterioration due to fungi is to be prevented.

The necessity for a careful conservation of timber in the United State is becoming more and more apparent (53,³ 54⁴). Measures, then, that will assist in preventing or reducing losses due to fungous attacks are of importance.

This bulletin presents a brief review of our knowledge of sap-stain and mold, a consideration of the causal organisms responsible for such deterioration in green wood stock, the results of the new investigations, and finally a summary of some of the important methods of control.

SAP-STAIN.

The "bluing," or sap-stain, of pine timber has been observed in Europe for many years. Both Hartig (17, 18) and Frank (11) refer to it in their investigations of plant diseases. Rudeloff (36) studied the effect of blue stain on the strength of pine wood. Münch (31) not only examined the properties of blued coniferous wood but also investigated the causal organisms and determined the optimum conditions for their development in the wood. In the United States considerable attention has been given to the subject by such investigators as Von Schrenk (41, 42, 43), Hedgcock (19, 20), Rumbold (37, 38), Weiss and Barnum (56, 57), and Bailey (5). Many of the investigations have been made in connection with the sap-stain of hardwoods as well as conifers.

³ The serial numbers (*italic*) in parentheses refer to "Literature cited" at the end of this bulletin.

⁴ These two reports on Senate Resolution No. 311 by the Forest Service of the United States Department of Agriculture may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 25 cents and 5 cents, respectively, per copy.

DEFINITION OF SAP-STAIN.

The term "sap-stain" refers to the blue, green, brown, or red discoloration which often may be observed in the sapwood of timber derived from several kinds of broad-leaved and coniferous trees. It must not be confused, however, with the superficial discolorations produced mechanically, i. e., by collections of dirt and coal dust, by deposits from the drip in leaky cars and sheds, or from the condensed moisture in kilns. Such deposits may occur upon heartwood as well as sapwood. Neither should it be confused with the common blue-purple stain apparent when rusty saws are used on certain green wood, such as oak. This stain results from the reaction between the tannic acids of the wood and the iron compounds from the saw. Finally, it must not be confounded with the variously colored superficial growths of molds or the more or less deep seated sap-rot, with its brown to bleached appearance and its tendency to produce a punky consistency of the sapwood itself.

There are two quite generally recognized classes of sap-stain: (1) The chemical stain, said to be produced by chemical reactions brought about through the agency of certain oxidizing enzymes present in the wood itself; and (2) fungous stains known to be caused by several species of fungi.

CHEMICAL STAINS.

Chemical stains due to enzymes cause discolorations in both the sapwood and the heartwood of sugar pine and hard maple (Tiemann, 51, p. 185; also Pratt, 34, p. 305-307). Such stains develop during air drying, particularly under warm and humid conditions, or in the kiln, and give more or less permanent discolorations to the wood, to wit, a brown stain in sugar pine (fig. 1) and a cherry color in hard maple. These defects cause degrading (34) and often result in financial losses. According to Bailey (5), when freshly cut sapwood of alder, birch, cherry, or red gum is exposed to the air during extremely warm and humid weather, chemical reactions often take place and within a few hours produce colored substances in the wood. Bailey (5) states that the microscopic examination of sections of such wood indicates that the colored substance develops particularly within the pith rays and the parenchyma cells. He states that certain soluble enzymes which assist in the oxidation of organic compounds and are of prime importance in the nutrition and growth of living organisms are widely distributed in plants and animals and may also produce post-mortem discolorations of certain organic compounds (see also Clark 8, 9). Yoshida (59) discovered in 1883 that an oxidizing ferment is responsible for the oxidation of the latex in certain species of *Rhus* and the formation thereby of black varnish, or lacquer. Investigations have also shown that discolorations in fruit juices,

vegetables, cereals, mushrooms, and various soft plant tissues are brought about through the agency of certain oxidizing ferments, the oxidases and the peroxidases (Asō 1, 2, 3; Clark, 8, 9; Kastle, 27). These ferments are sometimes distinguished by the production of a strong blue color in a tincture of guaiacum when used in the presence of oxygen or hydrogen peroxid (Haas and Hill, 16, p. 383).

Bailey (5) states that the activity of these oxidizing enzymes increases with the rise in temperature to a certain point, which may be called the optimum, and then decreases as the temperature is raised above this point. In almost every case, according to the same authority, the activity is entirely destroyed before a temperature of 100° C. (212° F.) is reached. He also states that the activity of these oxidizing ferments is diminished or destroyed by certain antiseptics and by other chemical substances. According to Asō (1, 2), such substances as tannin, sodium fluorid, and sodium silicofluorid, interfere with the color reactions normally produced by oxidases. Bailey (5) notes the strong similarity existing between the oxidizing activities of these enzymes and the chemical reactions responsible for certain kinds of sap-stain, namely, post-mortem oxidation with change of color produced by solutions in contact with the air and the similar variations in the activity of the discoloring agency in relation to variations in temperature.

If discolorations in sapwood are due to the activity of oxidizing enzymes, which, as has been shown, are rendered inactive by exposure to a temperature of 100° C. (212° F.), a logical prophylactic measure would be the submersion of timber in boiling water. Bailey (5), during the spring of 1910, performed certain dipping experiments.

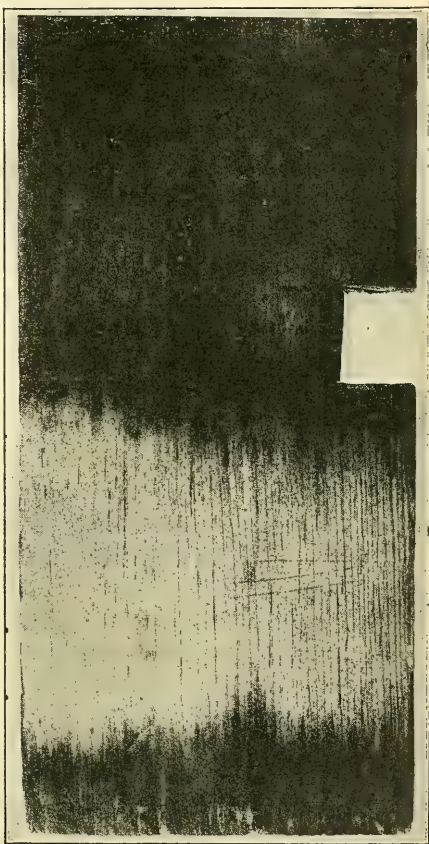


FIG. 1.—Board of sugar pine, showing chemical stain. The unstained area in the lower half of the illustration indicates the position of a crosser during the kiln treatment. The crosser afforded protection from oxidation. Photographed by H. D. Tiemann.

He found that when 1 by 3 by 6 inch boards of alder (*Alnus incana* Moench), white or gray birch (*Betula populifolia* Marsh), paper birch (*Betula papyrifera* Marsh), and various trees belonging to the rose family (Rosaceæ) were immersed in boiling water and then stacked under cover they would remain unchanged in color. Those boards which had been immersed in the boiling water and then placed in the most unfavorable conditions of high humidity and temperature in the open and exposed to the direct rays of the sun scorched on the surface. With the exception of this superficial scorching, no discoloration of the wood took place. On the other hand, untreated boards that had been cut from the same portion of the tree and subjected to similar conditions of temperature and humidity stained rapidly. Bailey (5) found that the rapidity and the depth to which the stain penetrates the wood varies with the temperature and the moisture, hot and humid weather being especially favorable for the production of stain. From a consideration of the results obtained, he concludes that sap-stain caused by oxidizing enzymes can be readily prevented by dipping the timber for a few minutes in boiling water.

Though chemical stains give more or less trouble in kiln-dried maple flooring and sugar-pine lumber, the discolorations may be prevented to an extent by the use of comparatively low temperatures (120° to 125° F.) and correspondingly low humidities (50 to 70 per cent; Tiemann, 51, p. 185). Because of their limited distribution and the fact that they do not impair the strength or durability of the timber, chemical stains in general can hardly be considered as having very great economic importance.

FUNGIOUS STAINS.

The second class of stains is produced by fungi. These fungi are disseminated by means of minute bodies known as spores. The spores may be produced in countless numbers and are blown about by the wind, washed along by the rain, or carried by animals, particularly insects. When, under favorable humidity and temperature conditions, they happen to lodge upon a substratum, such as the moist green sapwood of woods that contain the requisite food material, the spores may germinate and give rise to a mass of fine, usually septate threads, sometimes colorless at first, but often becoming darkened with age. This vegetative portion of the fungus is known as the mycelium, and the individual threads are called hyphæ. In some cases the hyphæ probably penetrate the wood but little, growing for the most part over the surface; in others, they may enter the sapwood through the medullary or pith rays. This does not result in the disintegration of the walls of the wood cells to any appreciable

extent. The starches, sugars, and oils stored in the sapwood and pith rays, together with the contained air and water, probably exert an influence upon the advancing hyphæ and limit largely the growth of the fungus to the sapwood and the pith rays, where the sap-stain is mainly to be found. Practically no invasion of the heartwood takes place (Von Schrenk, 41, p. 19). (Pl. I, fig. 3.)

THE SAP-STAIN FUNGI.

The relation of a fungus to the bluing of wood was first noted by Hartig (17, 18). He describes the organism which causes the so-called "bluing" of conifers, especially dead or dying pine that has been injured by caterpillars, as *Ceratostoma piliferum*. He notes that it may also appear in damp firewood. According to Hartig, the brown mycelium very quickly penetrates the trunk through the medullary rays. He states that probably on account of the deficiency in moisture content the heartwood is avoided by the mycelium, whereas the sapwood often becomes quickly invaded and decomposed. Although described by Fries (13; see also Berkeley, 6), who placed it in the genus *Sphaeria*, the fungus was later transferred by Fückel (14; see also Ellis and Everhart, 10) to the genus *Ceratostoma*. Saccardo (39) still later divided the genus *Ceratostoma* and placed those species which possess colorless spores in a new genus, *Ceratostomella*. Winter (58), in a subsequent revision of the family included the fungus as *Ceratostomella pilifera* Fries under the new genus. It is now known as *Ceratostomella pilifera* (Fries) Winter (Engler and Prantl, 29).

Figure 2 illustrates the fruiting bodies of this fungus. With the aid of a magnifying glass one may often see them clearly as stiff black hairs, approximately 1 millimeter ($1/25$ th of an inch) in length,⁵ swollen at the bases, and forming, en masse, a dark hairy covering on the ends and tangential surfaces of stained sapwood. These growths when well developed are sometimes referred to by lumbermen as "whiskers."

Many species of *Ceratostomella* have been listed by Saccardo (40). Though no reference is made to the fact, it is probable that a number of these stain wood.

The life histories of many species of *Ceratostomella* found on stained wood have been worked out by Von Schrenk (41), Hedgcock (19), and Rumbold (37) in this country and by Münch (31) in Europe. In connection with the study of several chromogenic fungi which discolor wood, Hedgcock developed in culture a conidial stage of *Ceratostomella* superficially resembling *Cephalosporium*. Münch and Rumbold associated a *Graphium* stage with the development of

⁵ In some species the length may exceed 2 millimeters.

Ceratostomella. During the extensive culture work of Hedgcock, however, extending over a period of four or five years and involving

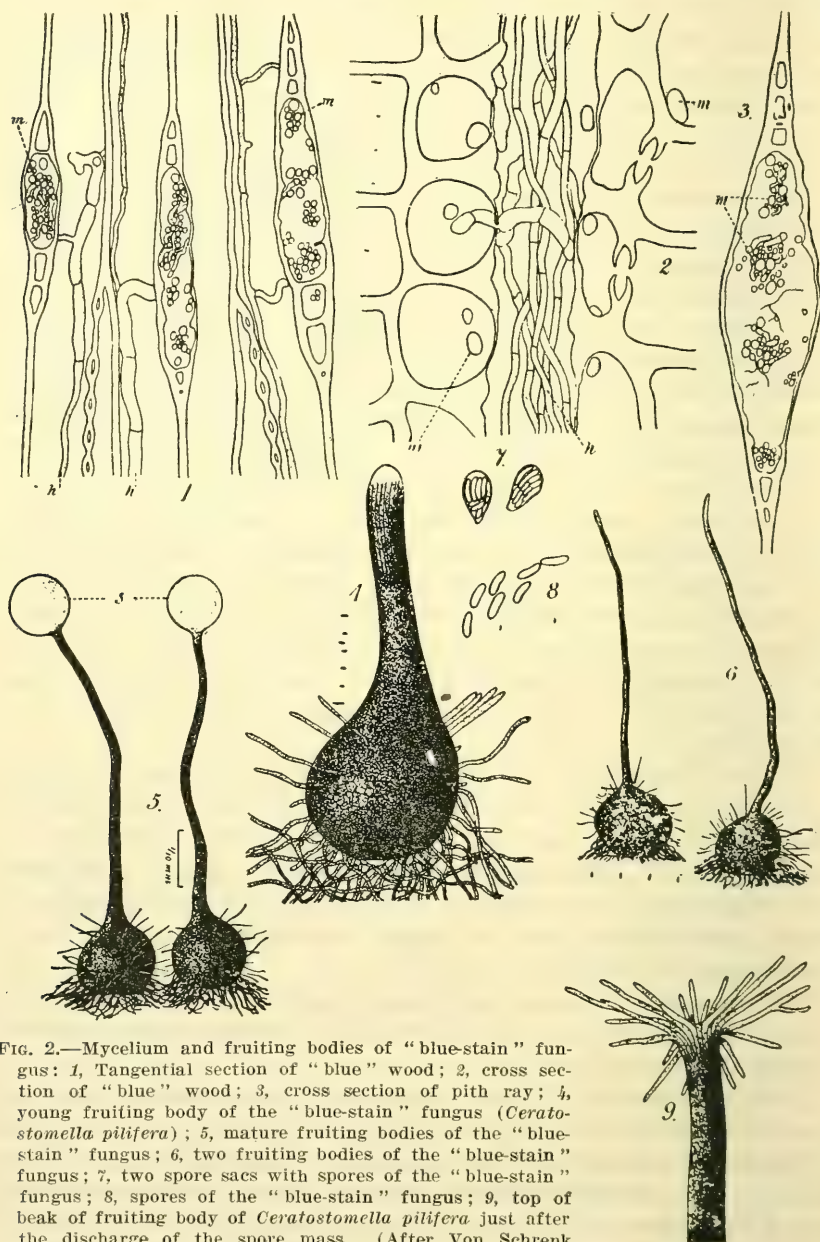
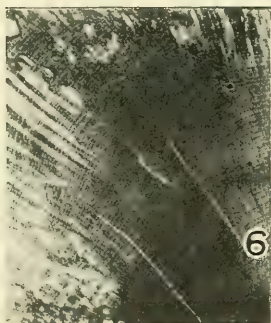
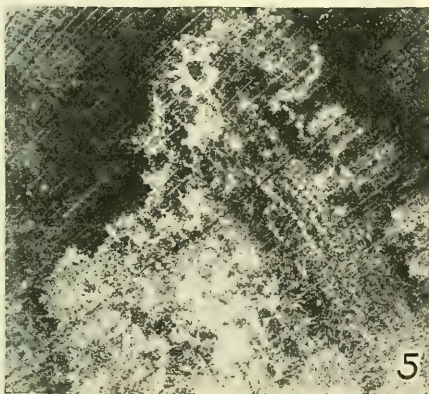
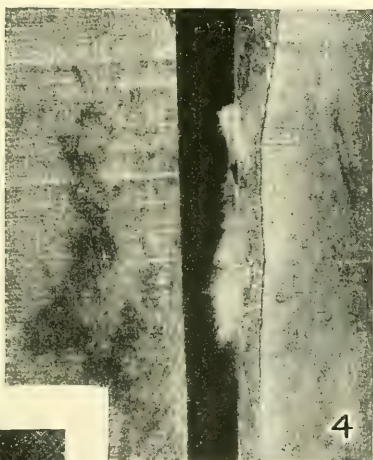
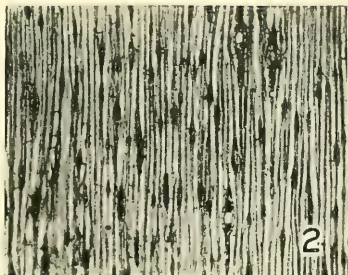
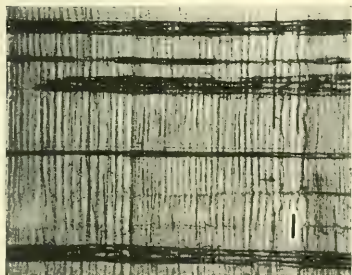


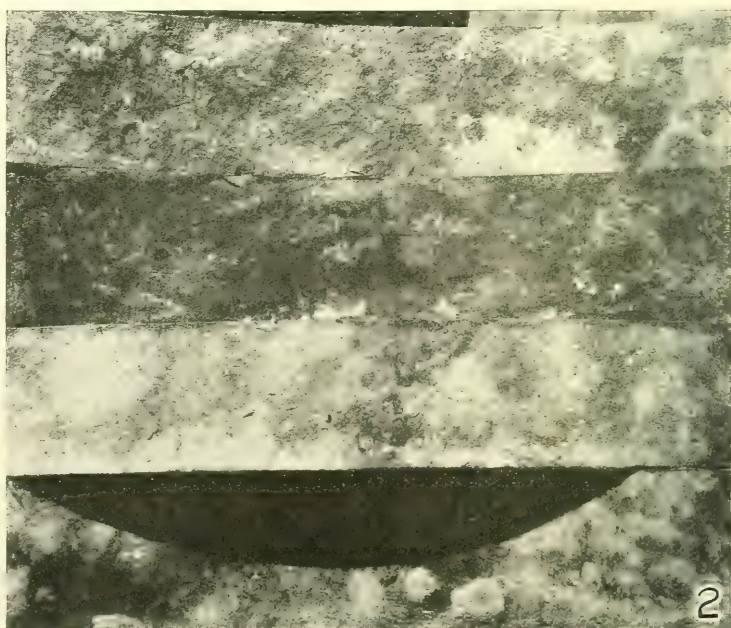
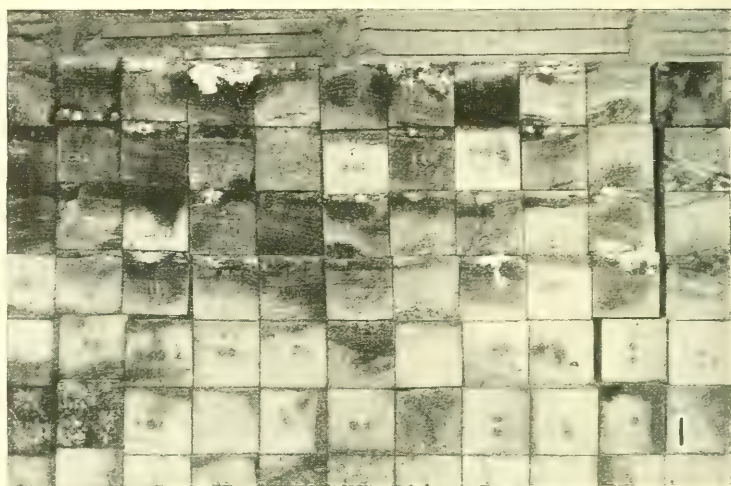
FIG. 2.—Mycelium and fruiting bodies of "blue-stain" fungus: 1, Tangential section of "blue" wood; 2, cross section of "blue" wood; 3, cross section of pith ray; 4, young fruiting body of the "blue-stain" fungus (*Ceratostomella pilifera*); 5, mature fruiting bodies of the "blue-stain" fungus; 6, two fruiting bodies of the "blue-stain" fungus; 7, two spore sacs with spores of the "blue-stain" fungus; 8, spores of the "blue-stain" fungus; 9, top of beak of fruiting body of *Ceratostomella pilifera* just after the discharge of the spore mass. (After Von Schrenk (32), pl. 7.)

a number of species of *Ceratostomella* from a variety of sources, no Graphium stage of this fungus was ever reported.



EXAMPLES OF WOOD INFECTION.—I.

FIG. 1.—Radial section of bull pine, showing hyphae of the blue-stain fungus growing in the pith rays. FIG. 2.—Tangential section of the same, showing many small hyphae growing into the adjoining cells. FIG. 3.—Log of southern yellow pine containing sap-stain. FIG. 4.—Mycelium of mold growing between hard-maule boards in a kiln. FIG. 5.—Mold on the end of a sawed red-oak billet. FIG. 6.—Maple billet containing sap-rot, a condition brought about through the agency of wood-destroying fungi. The surface has been polished to show more clearly the bleached and disorganized condition of the sapwood. (Figs. 1 and 2 are from Von Schrenk (41), pl. 8; fig. 4 is from a photograph by H. D. Tiemann.)



EXAMPLES OF WOOD INFECTION.—II.

FIG. 1.—Artificially infected blocks of red oak and white oak in the tile chamber ready for the steaming experiments performed at the Madison laboratory. The large white areas of mycelium on the ends of the blocks in the upper four rows are wood-destroying fungi and probably developed as a result of infection in the log. FIG. 2.—Sawed felloes of oak (species not known). Note the abundant growth of mold which had developed in the material during shipment and while in storage. Photographed by H. D. Tiemann.

Hedgcock (19) identified the following species of *Ceratostomella* as responsible for the discolorations produced in certain woods:

C. pilifera (Fr.) Wint., in the sapwood of several species of pine (*Pinus*), fir (*Abies*), oak (*Quercus*), and ash (*Fraxinus*).

C. schrenkiana n. sp., in short-leaf pine (*Pinus echinata* Mill.).

C. echinella E. and E., in freshly cut heartwood and sapwood of beech (*Fagus atropunicea* (Marsh) Sudworth).

C. capillifera n. sp., in wood of red gum (*Liquidambar styraciflua* L.).

C. pluriannulata n. sp., in blue sapwood of red oak (*Quercus rubra* L.).

C. minor n. sp., in Arizona pine (*Pinus arizonica* Eng.).

C. exigua n. sp., in dead and dying trees of scrub pine (*Pinus virginiana* Mill.).

C. moniliformis n. sp., in red gum (*Liquidambar styraciflua* L.).

Münch (31) split up *Ceratostomella pilifera* Fries into a series of new species, as follows:

1 *Ceratostomella pini*, the important blue-stain fungus of pine.

2. The pilifera group, distinguished by the secondary fruiting bodies:

(a) *C. piceae*, with an associated Graphium stage, possibly *Graphium penicillioides* Corda, in species of pine and fir.

(b) *C. cana*, with an associated but unclassified Graphium stage. This species he also found in pine wood.

(c) *C. coerulea*, having no associated Graphium stage.

With these species of *Ceratostomella* Münch includes two unrelated fungi, *Endoconidiophora coerulescens* and *Cladosporium* sp., as causing discolorations in coniferous timber.⁶

Von Schrenk (41), in his studies of the "blue wood" in dead and dying stands of the western yellow pine (*Pinus ponderosa* Laws.), found that the spores of *Ceratostomella* blown about by wind or carried by insects are often deposited in the exposed ends left by the breaking of branches or in the holes made by the bark and wood boring beetles. There, under the favorable conditions which usually prevail, they germinate and readily produce in a short time many colorless, branching hyphæ. The hyphæ grow into the bark tissues, then into the cambium, and from there into the medullary rays. With age the hyphæ take on a brown hue.

According to Von Schrenk (41, pp. 18, 19), "one of the first effects seen after the hyphæ have entered the medullary ray cells is the gradual solution of the walls separating the medullary ray cells from one another (fig. 2, 1, 2, 3). The walls which separate the ray cells from the neighboring wood cells may become very thin, as shown in the middle ray (fig. 2, 1), but they are rarely dissolved entirely. The intermediate walls, on the other hand, entirely disappear. This

⁶ In a recent publication, C. J. Humphrey (23) describes a fungus, *Lasiochaeria pezizula* (B. and C.) Sacc., as the cause of a blue-black stain in certain hardwoods, particularly beech and red gum. More detailed information concerning this fungus, as well as certain species of *Ceratostomella*, is given by E. E. Hubert (21).

leaves a tube, with a cross section having the shape of the cross section of the ray, extending into the trunk from the bark. This tube is sometimes filled entirely with a mass of brown hyphæ, the larger number of which extend in the direction of the ray (Pl. I, figs. 1 and 2). From the ray cells some hyphæ make their way into adjacent wood cells (fig. 2, 2; Pl. I, figs. 1 and 2).⁷ They grow along these, both up and down (fig. 2, 1), giving off branches to other wood cells. In this manner the whole wood body becomes penetrated by the brown hyphæ in a very short time after the first infection. The number of hyphæ in the wood cells proper, excluding the medullary ray cells and the cells of the wood parenchyma, is very small indeed. This is probably due to the fact that the fungus finds scant material upon which to live in the wood cells. The hyphæ are apparently able to puncture the unligified walls here and there, but they stop at that point. The writer was not able to demonstrate that the hyphæ could attack the lignified walls. In other words, the 'blue' fungus is one which confines its attack to the food substances contained in the storing cells of the trunk and to the slightly lignified walls of these storing cells." According to the same authority (41, p. 19), the resin ducts may be attacked in like manner (fig. 2, 3; Pl. I, fig. 2).

In the case of sawed timber it is quite probable that the fungous spores falling upon the surface of the sapwood find there the moisture and food material necessary for germination. Subsequently they give rise to a mass of mycelium, many of whose hyphæ enter the wood through the exposed medullary or pith rays and then probably invade the surrounding tissue, as explained by Von Schrenk.

SUSCEPTIBILITY OF VARIOUS WOODS TO SAP-STAIN FUNGI.

The sapwoods of many kinds of timber are susceptible to sap-stain, though the degree of susceptibility varies considerably. Among the conifers southern yellow pine, western yellow pine, sugar pine, and the spruces seem to be readily stained and in the case of the broad-leaved trees, red gum, red oak, white oak, and hackberry seem to be particularly susceptible.

Often there is a considerable difference between a species when grown on the dry uplands and the same species when grown under the moist conditions characteristic of the lowlands (Von Schrenk and Spaulding, 44). This difference in woods of the same species may be even more marked when grown in essentially different climates (Spaulding, 48). It seems to be the opinion of many lumbermen that timber grown in the South is more susceptible to fungous attacks than timber grown in the North. If differences in susceptibility do

⁷ E. E. Hubert (21) observed in the wood of scrub pine and northern white cedar hyphæ of *Ceratostomella* sp., which had penetrated tracheids and wood fibers for a distance of several cells from the medullary rays.

exist in such woods it is difficult to state whether they are due to dissimilarities in mechanical structure, to the relative proportions of contained air and water, or to the variety and amounts of stored food present in the wood parenchyma and medullary rays. It is probable that differences in environmental conditions, i. e., temperature and humidity as affecting the growth of the fungi, are important factors directly responsible (Roth, 35, p. 55-56).

STRENGTH OF "BLUED" WOOD.

Since the wood fibers are not appreciably impaired by the growth of the blue-stain fungus, there should be no apparent loss in the strength of the invaded wood. Rudeloff (36) found that the compression strength of pine is not affected by the presence of bluing fungi. Tests on the stained wood of western yellow pine conducted at Washington University, St. Louis, Mo. (Von Schrenk, 41) and later at the Forest Products Laboratory, Madison, Wis. (Weiss, 56; Weiss and Barnum, 57) proved that there is practically no diminution in the end compression or cross-breaking strength and hardness of the stained as compared with the unstained wood. In the case of heavily stained shortleaf pine, however, tested at the latter institution, there was found to be a slight decrease in the strength, toughness, and hardness as compared with unstained wood having the same moisture content. It may be safely stated that blued wood is practically as strong as unstained wood.

CAUSE OF THE COLOR IN "BLUED" WOOD.

The cause of the blue color in the wood has never been satisfactorily explained. R. Hartig (17, p. 66) ascertained that it arises from the presence of the brown fungous hyphæ in the intercellular spaces. According to Von Schrenk (41, p. 18, 25-26), it appears in the wood when the colorless mycelium begins to take on the brown hue characteristic of the mature fungus. Microscopic examination of the wood fibers taken from the blued wood reveals no indication of a blue color. While extracts of the blue wood with alcohol, ether, benzol, chloroform, alkalis, and acids differ in appearance from those obtained from clear wood, yet no blue tinge is apparent. Von Schrenk (41, p. 26) suggests that possibly "there is some pigment with a blue element in the 'blue' wood which is so faint that its detection in thin microscopic sections becomes almost impossible." Hedgcock (19, p. 110-111) states that "the brown color of the fungus apparently contains traces of a blue pigment whose color is transmitted by the wood cells of the pine more readily than the brown color." Münch (31, p. 3) concludes that the color is due to the arrangement of the mycelial threads in the wood. He cites, as some-

what similar examples, the blue color of thin milk, cigarette smoke, and the clear sky, wherein very fine particles are held in suspension in a transparent medium.

OTHER FUNGOUS ORGANISMS CAUSING SURFACE DISCOLORATIONS IN GREEN TIMBER.

In addition to the blue-stain fungi, there is another group, the molds, which commonly occur upon the freshly cut surfaces of green timber when stored under moist, warm, and stagnant conditions (Pl. I, fig. 5; Pl. II, figs. 1 and 2). Molds are occasionally found growing vigorously upon timber in kilns (Pl. I, fig. 4). This is especially noticeable when the atmosphere of the kiln is exceedingly moist or saturated and the temperature ranges from 90° to 110° F.⁸ or from 110° to 130° F. (Tiemann, 51, p. 186-187).

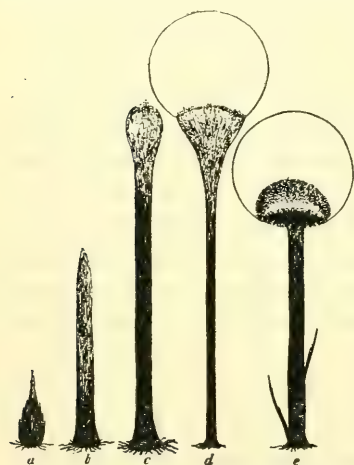
Hedgcock (19) showed that the blackening and browning so common in the green sapwood of pine (*Pinus* sp.), poplar (*Populus* sp.), tulip (*Liriodendron* sp.), red gum (*Liquidambar* sp.), oak (*Quercus* sp.), maple (*Acer* sp.), and several other woods can often be traced to species of *Graphium*. He cites:

G. ambrosiigerum n. sp., on Arizona pine (*Pinus arizonica* Eng.).

G. eumorphum Sacc., on wild red raspberry (*Rubus strigosus*) and related species.

G. atrovirens n. sp., on red gum (*Liquidambar styraciflua* L.).

FIG. 3.—Fruiting body of *Graphium* sp. (After Münch, 31.)



G. smaragdinum (A. and S.) Sacc., on red gum (*Liquidambar styraciflua* L.).

G. rigidum (Pers.) Sacc., on red oak (*Quercus rubra* L.).

G. aureum n. sp., on white pine (*Pinus strobus* L.).

G. album (Corda) Sacc., on beech (*Fagus atropunicea* (Marsh) Sudworth).

Graphium spp. are perhaps best known by the upright, cylindrical, occasionally branched fruiting bodies 1 to 3 millimeters in height (fig. 3). These are often brown to black in color and bear at the tips comparatively large and, in many cases, confluent globules composed of masses of spores embedded in a mucuslike substance. These spore masses, though usually cream color, vary somewhat in hue, and in some species are tinged with gray, brown, green, yellow, or red. While these are the organs of fructification commonly observed, other types less conspicuous and bearing the so-called secondary conidia have been demonstrated in culture by Hedgcock (19).

⁸ Information from the section of timber physics, Forest Products Laboratory, Madison, Wis.

Other fungi mentioned by Hedgcock (19) as blackening wood are: *Alternaria tenuis* Nees., *Stachybotrys alternans* Bon., *Aspergillus niger*, *Chaetomium* sp., *Stemonitis* sp., *Gliocladium* sp., *Hormodendron* sp., *Hormiscium* sp., and *Cladosporium* sp. The apparent discoloration in these cases is due either to the presence of colored hyphæ in or upon the surface of the wood or to a luxuriant superficial growth of colored spore masses. In no case is it due to the secretion of any pigment which is absorbed by the wood.

Hedgcock (19) names three other species—*Penicillium aureum* Corda, *Penicillium roseum*, and a *Fusarium* sp. formerly included under *Fusarium roseum*—which, due to the secretion of soluble pigments, actually stain the wood red, purple, or yellow, according to the alkalinity or acidity of the medium. These stains are superficial, however, and readily dress off when the lumber is planed. Many other molds grow readily upon green sapwood and give the timber a displeasing appearance, though they cause no deterioration in the strength of the wood. From the material collected by the writer and sent to the Madison laboratory there have been isolated over 40 distinct species of fungi. With the exception of species of *Ceratostomella* and *Graphium*, together with a species of *Fusarium* which was identified by Dr. Mabel M. Brown, graduate student at the University of Wisconsin, as *F. arthrosporioides*, this number consists of fungi popularly known as molds. The determination of the molds was made by Dr. Charles Thom and Miss Margaret B. Church, of the Bureau of Chemistry, United States Department of Agriculture. They are listed below:

Aspergillus flavus series.

Aspergillus niger.

Aspergillus repens.

Aspergillus versicolor group.

Cephalothecium roseum.

Citromyces sp.

Cladosporium sp.

Clonostachys sp.

Gliocladium sp.

Haplographium sp.

Monilia sitophila.

Mucor sp.

Oidium sp.

Penicillium asperulum or *puberulum*.

Penicillium brevicaulis series.

Penicillium commune.

Penicillium divaricatum.

Penicillium lilacinum.

Penicillium luteum.

Penicillium purpurogenum.

Penicillium roqueforti.

Penicillium rugulosum.

Penicillium solitum.

Syncephalastrum sp.

Trichoderma sp.

The great variety of genera and species here noted contains many earth dwellers and indicates that the molds commonly found upon green timber, especially during storage and transit, are for the most part soil forms whose spores have by accident fallen upon the moist surfaces of the sapwood and there found the conditions favorable for development.

It has generally been supposed that the growth of mold on wood is confined mainly to the surface or, at the most, to the superficial

layers, perhaps a few cells in thickness. H. Marshall Ward (55), however, in connection with certain experiments upon spruce blocks which had been artificially infected with *Penicillium* sp., notes that the examination of sections from cultures 3 months old showed that the hyphæ of this fungus had entered the starch-bearing cells in the medullary rays of the sapwood and had consumed the starch. The hyphæ were observed deep in the wood extending from tracheid to tracheid through the bordered pits. Miss A. L. Smith (46) notes the presence of a dark-brown hyphomycete in decaying timber. This mycelium had invaded the woody tissue and had apparently brought about a partial destruction of the medullary rays (see also Freeman, 12).⁹

During a series of experiments by the writer, cultures were taken from various points within red-oak blocks $2\frac{1}{2}$ by $2\frac{1}{2}$ by 10 inches long which had been cut from green sapwood and then artificially infected with 15 different fungi including 13 of the common molds.¹⁰

The results obtained seem to confirm Ward's experiments, for positive mold cultures were secured even from the center of these blocks. However, as far as known, the molds do not cause any serious disintegration of the cell walls in green timber and thus do not impair the strength of the wood to any appreciable extent. As in the case of the blue-stain fungus, it is the stored food within the cells that is the object of attack.

The principal objection to the presence of mold lies in the discoloration due to the masses of mycelium and the luxuriant clusters of fruiting bodies which often develop upon green sapwood, and sometimes the heartwood, under conditions of high humidity and temperature resulting from poor ventilation. However, these superficial growths are readily removed during sanding or planing operations. In many cases they can be readily brushed off. This is particularly true of material which has become surface dried.

An inspection of a carload of moldy timber is quite likely to produce an impression that is liable to react unfavorably upon the shipper. Moreover, the presence of much mold or sap-stain in timber indicates the existence of conditions which are favorable to the development of decay. Such material, then, should be viewed with suspicion, but not of necessity with unfavorable discrimination.

FACTORS WHICH FAVOR THE GROWTH OF SAP-STAIN AND MOLD FUNGI.

The development of fungi is dependent upon four factors—a supply of air, containing the essential element oxygen; the requisite

⁹ McBeth and Scales (39) list a considerable number of molds that are apparently able to destroy cellulose, though they act differently toward different kinds of cellulose.

¹⁰ See page 29 for the list of fungi used in this experiment.

amount of moisture; a temperature range within certain limits; and the necessary food substances.

Air.—Fungi require oxygen for their growth. This is supplied as one of the constituents of ordinary air. Even under storage conditions the supply is ample. Stagnant air containing a considerable amount of moisture is favorable to the growth of fungi in the timber, in that it prevents the drying of the wood. Timber entirely submerged in water is practically immune from fungous attacks, since the supply of oxygen is cut off.

Moisture.—The extent of the growth of sap-stain and mold fungi is largely dependent upon the amount of moisture present in the substratum. This moisture content in green timbers of different species as well as in the sapwood and heartwood of a particular species may vary considerably. Thus, according to Tiemann (51, p. 106; 33, tables), the green sapwood of conifers may contain from 100 to 150 per cent moisture,¹¹ while the heartwood, probably being near its fiber saturation point, contains about 30 per cent. In the case of the hardwoods, both heartwood and sapwood may contain from 60 to over 200 per cent moisture. Frequently, however, there is present a greater quantity of free water in the sapwood than in the heartwood (Tiemann, 51). In air-dried timber the amount of moisture may be reduced to anywhere from 8 to 18 per cent, according to the climate. In kiln-dried material it may be reduced to 3 to 15 per cent moisture, depending upon requirement and uses. This will explain why mold and sap-stain, so frequently found in green timber, are absent in thoroughly air-seasoned or kiln-dried stock. Air currents will often surface-dry the timber to an extent that will make it practically impossible for fungi to grow thereon.

The relative quantities of water and air found in the wood, according to Von Schrenk (43), are the most important factors in the control of the rate of growth and spread of the sap-stain fungus. He cites Münch's experiments (32) on artificially inoculated pine blocks,¹² differing only in the relative amounts of contained water and air. These experiments seem to indicate that the growth of the fungus is inhibited when the normal winter water content of the wood is raised to an amount that will insure a consequent reduction in the volume of contained air to at least 15 per cent, based on the volume of the fresh wood. According to Münch (32) an air content of 42 per cent, brought about through a reduction of the normal winter water content of the wood; is the optimum for development of the fungus in the wood. Münch (31, p. 59-62) states that the sap-stain fungus at-

¹¹ Unless otherwise stated, all percentages of moisture content are based upon oven-dry weight.

¹² The blocks in this case were artificially inoculated with the conidia of *Ceratostomella coerulea*.

tacks recently felled trees, but does not penetrate deeply, owing to the high water content of the wood. He also states that the mycelium of the fungus readily penetrates throughout the sapwood of winter-felled wood when the loss in water content amounts to 10 to 20 per cent. Moreover, the growth in moist wood takes place for the most part in the older layers of the sapwood, or those in proximity to the heartwood. Finally, Münch concludes that the sap-stain fungus is capable of infecting the living tree, thus becoming parasitic, provided the fungous spores find entrance to the sapwood through injuries to the bark, such as those produced by bark-boring beetles; and that conditions favorable for fungous growth, namely, a reduction in the water content and a corresponding increase in the air content of the sapwood, are brought about through disturbances in the root system of the tree.

In this connection certain investigations by Snell (47) on the relation of the amount of decay to the density of the wood should be mentioned. Five fungi which had been found to cause the rotting of structural timber in New England cotton mills were grown upon blocks of loblolly-pine sapwood and Sitka spruce. Several series of these blocks, each series containing a different percentage of moisture, were used in these experiments. The results obtained with loblolly pine agreed in the main with those of Münch (32) upon Scotch pine, a wood of about the same density. In the case of Sitka spruce, a wood of considerably less density, however, it was found that the limits of moisture content favorable for fungous growth were raised. In other words, "the values representing the upper limits for decay will vary inversely with the density of the wood."

Temperature.—It has been clearly demonstrated in a number of temperature tests¹³ upon some of the molds derived from infected timber that these fungi grow readily between certain limiting temperatures. Beyond these, they cease to show any signs of activity. The optimum temperatures are commonly those which obtain during the late spring and summer months in certain parts of the country, particularly in the South, i. e., 80° to 85° F. It is probable, however, that each species has its own characteristic range.

Food.—Sap-staining fungi and molds have been shown in cultures to live upon quite a variety of foods. Being devoid of chlorophyll they can not, like the higher plants, manufacture their own food, but must depend upon that already available. The medullary rays and wood parenchyma of green sapwood often contain certain starches, sugars, and oils which represent the stored food of the tree. These are the substances upon which sap-staining fungi probably depend for their existence.

¹³ These tests were conducted at the Forest Products Laboratory, Madison, by Mrs. Rose Harsch Lynwalter.

When supplied with the essentials necessary for growth, fungi develop rapidly and often reproduce abundantly. Deprived of any or all of these factors, however, the vegetative portion, i. e., mycelium, ceases to grow and eventually dies. In some cases, as, for instance, certain molds, the spores may retain their vitality for long periods under extremely unfavorable circumstances. When favorable conditions return, these spores soon germinate and often develop an abundant growth of mycelium within a few days. Fruiting bodies, sometimes bearing countless spores, may then make their appearance, and the life cycle is repeated. The ideal conditions for growth are often to be found in green timber containing a high percentage of sapwood when exposed to the stagnant atmosphere of the woods, poorly ventilated sheds, warehouses, and cars during warm, sultry, or rainy weather. Under such circumstances the sapwood may become thoroughly infected within a few days. Sap-stain may thus appear soon after infection with spores or mycelium of the sap-stain fungi. Wood-rotting fungi may also get a good hold upon timber under such conditions, and symptoms of incipient decay later become apparent (Pl. I, fig. 6).

DURABILITY OF STAINED OR MOLDED WOOD.

Since the blue stain and mold fungi cause little or no dissolution of the wood fibers, they do not affect directly the durability of the timber. If properly piled and dried, stained or moldy wood stock free from decay should not deteriorate further from the action of the fungi. However, the conditions which favor the development of sap-stain, mold, and sap-rot are much the same, namely, the presence of spores or mycelium of the particular fungi capable of producing these defects in wood, a substratum containing the requisite food material, moisture, and a high relative humidity (75 to 100 per cent), a temperature of 70° to 100° F., and a lack of circulation of the air, or stagnation, which retards or prevents the proper drying of the timber. There seems to exist among many lumbermen a false notion that mold and sap-stain represent early stages in the development of sap-rot, or "dote," as it is commonly called. While the presence of an abundant growth of mold or sap-stain in green stock indicates conditions which are likely to favor the growth of rot, it is well known that the rot is caused by a distinct group of true wood-destroying fungi which develop independently.

Molds in general develop rapidly. Hence, they may be often found growing profusely on green timber already infected with rot-producing fungi long before the latter have exhibited any noticeable evidence of their presence. It is possible, however, for wood destroyers to infect and bring about the disintegration of wood which contains no trace of mold or any other organisms.

LOSSES DUE TO SAP-STAIN OR MOLD.

INSANITARY PRACTICES IN THE HANDLING OF GREEN WOOD STOCK.

As a result of investigations in the woods, inspections of many car-loads of green timber and dimension stock upon arrival at the mill, examinations of green and seasoned manufactured stock upon arrival at the vehicle factory, and talks with practical millmen and lumbermen, the writer is convinced that a considerable amount of the damage to vehicle stock, due to fungi, is brought about through the use of infected raw material. Many of the infections take place in the woods, as a result of insanitary practices in the handling of logs, bolts, and split billets. In many instances, during warm and humid weather logs and bolts have been allowed to lie in the woods for weeks. Under such conditions sap-stain is almost certain to follow. Moreover, the liability to attack by wood-destroying fungi is greatly increased.

Split billets, instead of being cross piled on dry foundations, are sometimes thrown carelessly about the stump and left until a convenient time for hauling arrives. Under favorable circumstances it takes but a few days for certain fungi to gain a good hold on such stock, and unless later checked or destroyed by some process such as kiln drying, they may produce a permanent stain or decay in the sapwood.

It is quite probable that a serious shortage of cars suitable for handling the logs, bolts, and billets may prevent at times the rapid movement of raw stock to the mills. This results in the accumulation of material in the woods and railroad yards and contributes to conditions in many cases favorable to the development of the fungi. Frequently box cars are used where in normal times the more open and consequently better ventilated types of car would be employed.

Failure to observe proper measures during storage, such as the use of dry foundations for logs and bolts, the cross piling or stripping of billets on dry foundations sufficiently high to give suitable ventilation from beneath, and the storage of stock in properly ventilated sheds, has furnished conditions suitable for the development of mold, sap-stain, and decay in such material.

A few millmen seem to have the mistaken idea that an abundant growth of mold on green stock serves to protect it from checking by preventing evaporation from the surface of the wood and actually absorbing, or possibly condensing, moisture from the surrounding atmosphere and then transmitting it to the wood. The fungus derives its moisture from the wood, not the air. Its presence, however, often indicates a high humidity in the immediate vicinity, a condition which prevents the drying of the wood and thus favors the growth of fungi. It is quite probable that the phenomenon known as gutta-

tion, i. e., the collection of minute drops of excreted water upon the fungous growth, is responsible for the misconception.

In some instances split billets upon being unloaded from the cars are thrown in a pile beside the track, sometimes upon damp soil, there to remain for perhaps a month or until opportunity can be found for removal to storage sheds. Losses due to fungi are a natural consequence of such treatment.

It has taken time for those unaccustomed to the handling of green stock to work out satisfactory methods which would provide proper ventilation of dimension, sawed, or turned stock during transit. Meantime, many shipments have been seriously damaged. Of the different forms of stock, the sawed billet, the rim strip, and plank have given the most trouble. Losses are not confined to such stock, however, for turned spokes and hubs, unless properly safeguarded during transit, are liable to stain and mold.

Sawed billets often arrive at the factory in a badly stained condition. It is probable that material containing fungous infections sometimes finds its way into their manufacture. The squared surfaces lend themselves to close piling and thus to the formation of masses wherein sufficient ventilation is impossible. Rim strips also frequently become badly stained while in transit, as a result of the same causes, together with the fact that some manufacturers require such stock to be close piled in closed box cars and even sprayed with water to prevent checking. It is unfortunate that the conditions necessary for the prevention of checking in green stock are as a general rule favorable to the growth of fungi, and vice versa.

ECONOMIC IMPORTANCE.

The presence of much sap-stain and even mold in timber is considered by some lumbermen as a defect. Therefore, degrading of material thus affected, with consequent loss in monetary value, may result. Such unfavorable discrimination is due to the notion that stained or moldy material is not as sound as clear stock. In the case of molds, it is an easy matter to remove the surface blemish by the simple process of sanding or planing. With sap-stain, however, the removal of the discoloration depends entirely upon the depth to which the mycelium has penetrated. In some cases the stain may extend to the heartwood. It is evident that it can not under such circumstances be removed by the processes referred to.

The presence of much stain will prevent the use of timber for purposes where color, texture, and clearness of grain are of prime importance. Basket and box veneer, interior finish, flooring, and furniture stock which are to have no protecting coat of paint must be free from stain. Discrimination, however, should not be made

against sap-stained or moldy stock that is to be covered, provided there is no incipient decay associated with it.

The reduction in the value of stained lumber sometimes amounts to \$2 or more per 1,000 feet, board measure, and perhaps one-fourth of the annual mill cut of the United States is attacked. In one year it was estimated that the total losses from sap-stain amounted to between 8 and 9 million dollars (Weiss, 56; Weiss and Barnum, 57; see also Pratt, 34). The amount in any locality, however, depends upon the climate, the season, and several other factors.

Weather conditions have a marked influence upon the amount of damage to freshly cut timber in the woods or to green stock in storage and in transit. During warm and moist weather such stock will sometimes stain badly and in a short time, unless it is properly safeguarded. This, of course, is due to the fact that the warm and humid conditions stimulate the development of the fungi. It follows, then, that the greater losses from sap-stain, sap-rot, or mold should be expected during the warmer months, and especially during those months in which both high temperatures and high humidity normally prevail. As a matter of fact, this is the case. In the months of April, May, June, July, and sometimes August and even September, depending upon climatic conditions, the greatest damage occurs. In the South, owing to the prevailing high temperatures and relative humidities, the losses are often extremely severe. The greatest losses occur in low-grade coniferous lumber, especially the southern pines, owing partly to the high percentage of sapwood and partly to the fact that the low-grade lumber is seldom kiln dried, but is stacked in the yard to air season. Under such circumstances, unless unusual precautions are observed, it is very liable to the attacks of the sap-stain fungi.

From replies to the questionnaires sent out by the wood-stock committee to contractors and producers of wood stock regarding sap-stain and mold in vehicle stock and from the data derived from the personal investigations of the writer, it was learned that these losses are dependent largely upon the manner in which the stock is piled in the cars and sheds during transit or storage. The losses average less than 10 per cent, but may reach from 25 to 75 per cent. The writer was informed that because of such damage to green spokes during the summer of 1918, sometimes as many as 50 per cent in a carload lot were culled. When turned spokes were selling at \$150 per 1,000 feet b. m., the loss on a carload containing perhaps 12,000 escort spokes, $2\frac{1}{2}$ by $2\frac{1}{2}$ by 27 inches, was evidently considerable, perhaps amounting to hundreds of dollars. One firm reported that it had knowledge of entire carloads being destroyed. In some instances cars had gone astray and had finally reached their proper destina-

tion after one or two months on the road. Losses in those cases were often practically complete. Sixteen different firms reported that for the year 1917 their individual losses due to "heating in transit," as staining is sometimes explained by lumbermen, varied from \$100 to \$5,000. One company reported the losses as varying from \$25,000 to over \$75,000 in different years.¹⁴

CONTROL MEASURES.

A great many attempts have been made to devise measures for the control of sap-stain and mold in green timber. With the exception of kiln drying, however, none of these has proved entirely satisfactory. When tried under circumstances unfavorable to the growth of fungi, some of these measures have met with considerable success, but when put to the test under conditions which stimulate fungous development, they have often failed. For the most part they have been prophylactic rather than curative in nature. However, it is believed that many of the following measures, although not entirely effective, will assist materially in reducing losses due to sap-stain, mold, and incipient decay in green stock.

HANDLING IN THE WOODS.

AUTUMN AND WINTER CUTTING.

Many lumbermen (15) think that, where possible, timber should be cut in the autumn and winter. While this is probably true, the reason often given is incorrect. The statement is usually made that winter cutting is better because the "sap is down." It has been shown by T. Hartig (33, tables; Janka, 26) that during the spring when the growth is most active the tree sometimes contains less water than in the winter. It is probable that the changes in moisture content which do take place are confined mainly to the sapwood. It is true that the movement of sap is much more rapid at the time of active growth and that there are important chemical changes which take place therein during the different seasons of the year. In the winter, insoluble starches and gums are stored in the sapwood. During the spring these are changed to soluble sugars and are borne through the living tissues. The sapwood of summer-cut logs, therefore, contains soluble foods which render it extremely susceptible to attacks by fungi during the warm months when these organisms are most active. Winter-cut logs, on the other hand, have an opportunity to season under conditions less favorable for fungous growth and by the time warm weather

¹⁴ National Implement and Vehicle Association and other Vehicle and Vehicle Parts Manufacturers. Information Division of the Wagon and Vehicle Committee and the Wheel Manufacturers' War Service Committee. Wood Stock Committee. Sap-stain and mold in transit. Nat. Implement and Vehicle Assoc., etc., Bul. 30, 5 p. 1918. A. B. Thielens, chairman. Typewritten.

arrives will have dried to a degree which will render them less susceptible to fungi (Roth, 35, p. 57).

In the bottom lands of the South, however, autumn and winter cutting may not always be feasible owing to the wet and muddy conditions then prevailing, which make hauling difficult, if not impossible.

Incidentally, leaf seasoning (Tiemann, 51), i. e., girdling trees while in full leaf and then allowing them to remain, often for years or until the leaves have entirely shriveled up, with the idea that much of the free water in the sapwood will be drawn off by transpiration through the leaf surfaces and thus prevent sap-stain, does not seem to be practiced in the regions visited by the writer. Although this method is said to be common in the seasoning of teak in India and has been advocated by some as applicable to gum in this country, yet it does not seem to meet with general approval, because it exposes the timber to the ravages of insects and to fungi causing decay.

RAPID HAULING.

One of the precautionary measures to be observed, especially during the late spring and summer, is that of hauling timber immediately after felling. Raw stock can not be gotten out of the woods and to the saw too rapidly. It is possible for fungous infections to take place at all times of the year on the exposed surfaces of freshly cut timber. These develop more rapidly, however, during warm, humid weather, and especially under the conditions which obtain in the woods.

STORAGE IN THE WOODS.

If it is found necessary to allow logs and bolts to remain in the woods, they should be so separated that the ends are left several inches apart. If the sawed ends remain in contact, fungi are liable to develop between them. Some have recommended that logs that are to remain in the woods during the summer be painted on the exposed ends with creosote (Von Schrenk, 42). It has been considered advantageous by some (Von Schrenk, 42; see also Hartig, 18) to remove the bark from logs that must of necessity be left in the woods for an extended period. Advocates of such treatment state that the peeled surfaces soon become air-dried and consequently provide insufficient moisture for the germination of any fungous spores that may fall thereon. In order to keep such logs off the damp ground and thus assist in the air-drying process measures must be taken to provide some sort of temporary foundation free from stain, mold, or rot.

When it becomes necessary to store split billets in the woods, they should be piled with only two billets in a course and should rest upon

a foundation located on dry ground and consisting, where possible, of billets of split heartwood free from rot.

HANDLING RAW STOCK IN TRANSIT.

TYPES OF CARS.

In shipping green stock to be used in the manufacture of vehicles, etc., the following types of cars have been preferred:

Flat cars	logs (fig. 4).
Gondolas or stock cars	bolts (fig. 5).
Stock or vegetable cars	split billets or dimension stock.
Ventilated box cars	lumber or dimension stock.



FIG. 4.—Unloading logs from a flat car. This is the type of car usually used for the shipment of logs.

PROVISIONS FOR THE PROPER VENTILATION OF STOCK IN TRANSIT.

Well-ventilated types of cars should be selected where possible, if staining and molding are to be prevented (figs. 4 to 10). Preparatory to use, these cars should be thoroughly swept free from rubbish, damp sawdust, lime, or manure. In the case of box cars, it is important that the roofs be carefully inspected to make sure that they are water-tight. If it becomes necessary to use box cars for the transportation of split billets during the late spring and summer months, it is suggested that the billets be ricked and that strips or occasional crossers of the same stock at intervals of 12 to 16 inches be used to assist in the ventilation of the pile. Side doors should be open and both doorways boarded up, leaving at least 1½-inch spaces between the boards. If box cars are equipped with small

end doors of the ventilating type, these doors should be left open and the doorways cleared to prevent the stock from working out during transit. Lumber shipped in box cars must be stripped.

HANDLING RAW STOCK IN THE YARDS.

STORAGE OF LOGS AND BOLTS.

When piling or cording logs and bolts in the yard for storage, it is important that they be kept off the ground by the use of clean skids or permanent foundations of seasoned fungus-free planks, stone, or cement. Such foundations should be placed on well-drained soil free from underbrush or weeds that might interfere with proper ventilation from beneath.

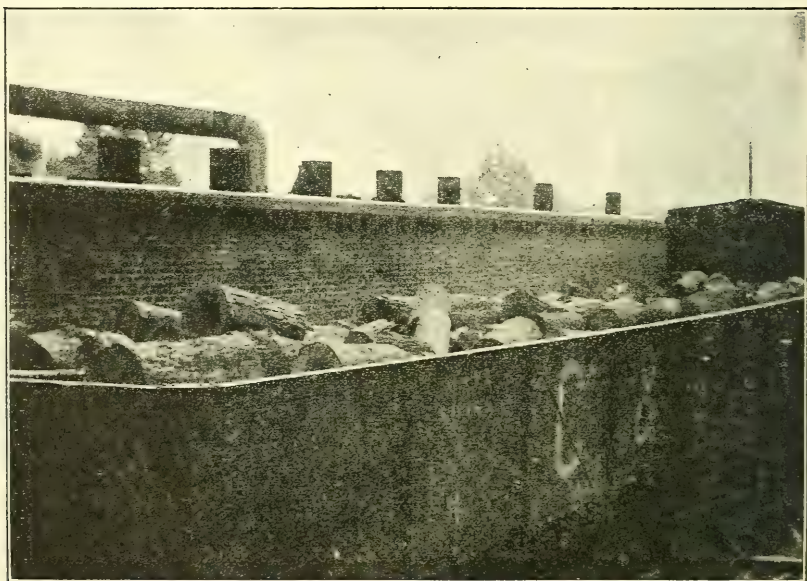


FIG. 5.—Bolts loaded in a gondola car. Gondolas, stock, or vegetable cars are best adapted to the transportation of this type of raw stock.

STORAGE OF BILLETS.

Billets that are not turned at once should be stored upon dry foundations and in properly ventilated sheds (fig. 11). When sufficient storage space is available, the method of piling used by one of the large wheel manufacturers in the North, shown in figure 12, is recommended.

STORAGE OF GREEN LUMBER.

The methods of piling lumber are pretty well understood and need little explanation here (?).¹⁵ In general, it is well to select a location

¹⁵ For information concerning this point, the reader is referred to Bulletin No. 552, United States Department of Agriculture (7), copies of which may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 10 cents per copy.

on well-drained soil free from weeds and one which will allow the prevailing winds to blow through the sides rather than upon the ends of the stacks.

Care should be taken to provide suitable foundations consisting of metal or well-seasoned heart stock, preferably creosoted and resting upon piers of creosoted wood or, better, of stone, brick, concrete, or metal. All foundations should be sufficiently high to allow for ventilation vertically through the stacks. Moreover, there should be ample space between the stacks to permit a free circulation of the air around them. Finally, it is important that narrow strips, perhaps 1 inch wide and at least 1 inch thick, of well-seasoned, kiln-dried, or chemically treated wood be used between all courses and that they be carefully placed in vertical alignment to prevent warping of the stock.¹⁶

HANDLING AT THE MILL.

EARLY MANUFACTURE.

Logs, bolts, and split billets should be sawed into dimension stock or planks and manufactured as soon as possible. This will do much toward safeguarding the material by reducing the time in storage.

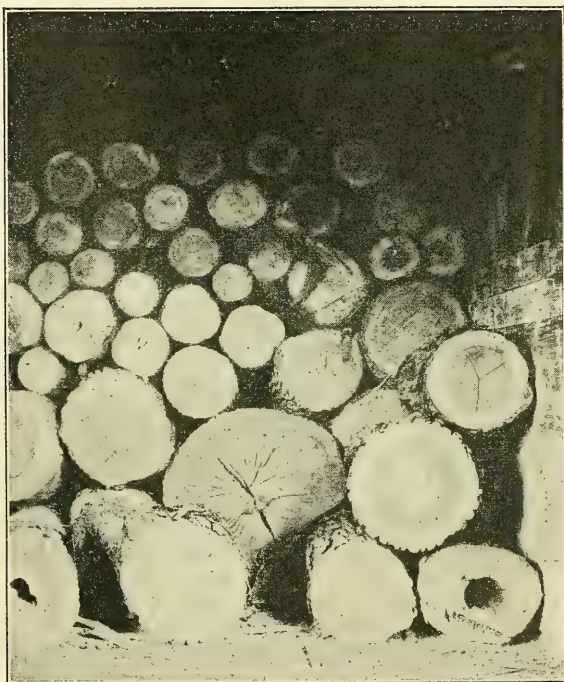


FIG. 6.—Bolts piled in a box car. Note the débris on the floor of the car. Bolts are likely to suffer from fungous attacks when shipped in box cars with the doors closed.

AIR SEASONING.

Provided kilns are not available, the dimension stock should be seasoned from six months to a year or more, depending upon the

¹⁶ The general sanitation of lumber yards and the proper methods to be observed in the piling of timber to prevent or reduce losses in storage due to fungi, together with a consideration of the more common rot-producing organisms, are clearly described by Humphrey (22), in Bulletin No. 510, United States Department of Agriculture. Copies may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 20 cents per copy.

size and kind of material.¹⁷ When sufficiently dry, shipments in closed box cars will suffer little or no loss from sap-stain or mold. In all cases where air seasoning is resorted to, unless great care is exercised in providing for ample circulation of air through the stock by such means as open piling, fungous and insect troubles are likely to develop. It is absolutely necessary to strip or cross pile the stock upon dry foundations. For purposes of stripping, kiln-dried or chemically treated strips 1 inch wide and at least 1 inch thick should

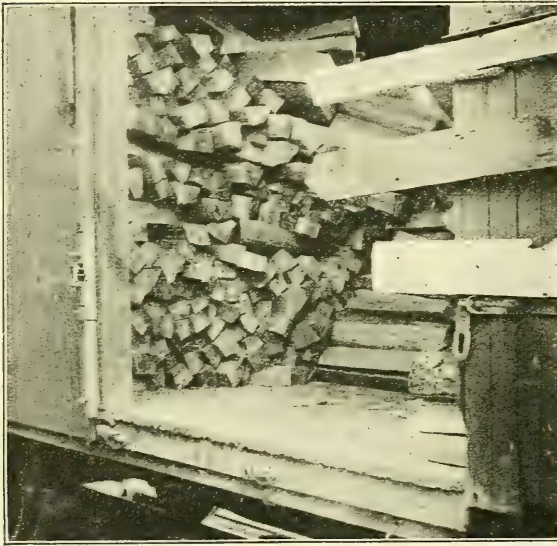


FIG. 7.—Split billets piled in a box car. When occasional billets are used as crossers and the doors of the car are cleated open this type of spoke stock suffers but little while in transit.

be used between courses. All sheds for the storage of this material should be dry and well ventilated.

operated on a scientific basis and are so situated that stock can be moved rapidly, less concern need be given to fungous troubles. Kiln-dried spokes can be bundled or close piled in dry warehouses or in ordinary box cars and shipped without loss.

Material kiln dried directly from the saw has been shown to be just as good as air-seasoned stock (Tiemann, 51, p. 300) and in many cases much better as far as strength, toughness, and freedom from defects are concerned. Moreover, the time necessary for seasoning can often be reduced from one year to three weeks or from three to five years to as many months.

KILN DRYING.

By far the most effective and quickest method of treating green stock, as a prophylactic measure, to destroy fungi or insects and to reduce shipping weight, is to subject the material to proper kiln drying. When producers are equipped with, or have access to, modern kilns op-

¹⁷ The reader is again referred to Department Bulletin No. 552 (7) for information concerning the seasoning of wood.

Kiln drying reduces shipping weight; makes the lumber fit for almost immediate use; eliminates or reduces losses due to insects,¹⁸ or to checking, rotting, staining, or molding; improves the quality of the lumber; reduces the amount of yard space; and saves the tying up of capital and carrying costs (Tiemann, 51, p. 4, 5).

It is possible that where several producers are located within a few miles of one another, a battery of modern dry kilns, operated according to the most approved methods (possibly on the community plan) might solve the problem of cost of installation and operation.

In dry kilns, stripping or cross piling the stock and providing means to prevent stagnation of the confined air are absolutely necessary if the development of mold is to be avoided. The water spray kiln devised at the Forests Products Laboratory represents one of the latest developments in the temperature and humidity-controlled type of kiln.¹⁹

During the first few weeks of kiln drying, when the humidity is high and the temperature ranges from 80° to 105° F., an abundant

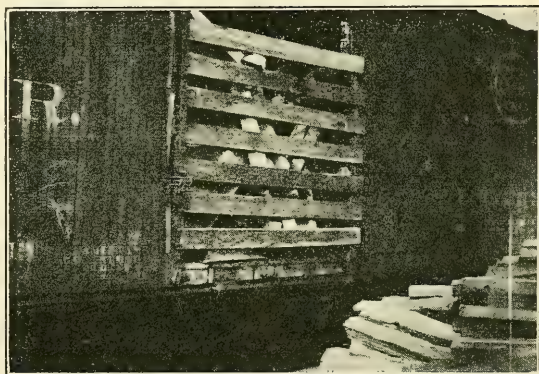


FIG. 8.—Split billets loosely piled in the areaway between the doors of a box car. The doorways are loosely boarded up to allow for ventilation of the car and at the same time prevent the stock from working out while in transit.

growth of white mycelium occasionally forms between the courses and interferes more or less with the circulation of the air in the kiln. This is due to the presence of mold fungi, and it usually indicates stagnation in the kiln (Pl. I, fig. 4). Steaming for one hour at a temperature of 160° to 180° F. has been found effective in destroying or at least checking the growth of this mold (Tiemann (51), p. 187).

¹⁸ Powder-post beetles, however, are said to cause considerable damage at times in seasoned stock; in fact, these beetles do not work in green stock.

¹⁹ A complete description of this kiln is given in Bulletin No. 509, United States Department of Agriculture (52), a copy of which may be procured from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 5 cents. Further information concerning the design and installation of this kiln is given in Bulletin No. 894, United States Department of Agriculture (50), to be procured from the same source at 10 cents a copy.

STEAMING GREEN STOCK AS A CONTROL MEASURE.

METHODS COMMERCIALY EMPLOYED.

Steaming certain kinds of stock (green gum lumber, birch hubs, spokes, and sawed felloes of red or white oak) is sometimes resorted to as a means of reducing shipping weight by hastening drying or to even up the color and reveal defects in the wood.

In the steaming of green gum lumber a large steel tank, or preparator, is employed. The lumber loaded upon trucks is run into this preparator and steamed for perhaps 15 to 30 minutes at pressures of 20 to 30 pounds (figs. 13 and 14). Provided this lumber is

then carefully open piled, it remains clean. When close piled or when exposed to adverse weather conditions, however, it may mold almost as readily as untreated green lumber.

Hubs, sawed felloes, and turned spokes green from the saw are sometimes steamed at atmospheric pressure. At one plant visited, green birch hubs were stacked in large cement boxes and subjected to exhaust steam for 24 to 36 hours, depending upon the size of the

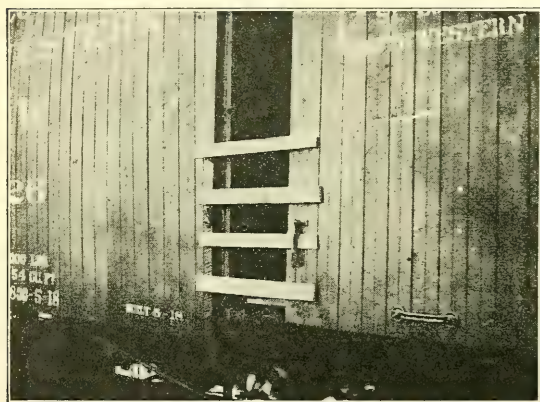


FIG. 9.—A box car loaded with split billets upon its arrival at the spoke mill. The method of loosely boarding the doorway, as shown in figure 8, is preferable in that there is less danger of the stock working out while in transit. When, however, the masses of billets are held in position by supports, or when vertical boards are nailed a few inches back of the cleats, this method may be used. Both provide for the ventilation of the stock.

hub. At the end of that time the steam was shut off and the hubs were allowed to cool for perhaps 10 hours. The hubs were then carried to a ventilated warehouse and stacked, zigzag fashion, to provide for ample circulation of the air through the inside as well as around them. In this manner an even drying was secured. Two to three weeks was considered a sufficient length of time for the necessary air drying previous to shipping. During the warmer months, stock cars were used as means of transportation.

The steaming of gum and birch is a comparatively simple process. But in the case of woods that check readily, such as oak, this treatment requires considerable care.

THE EXPERIMENTAL STEAMING OF RED-OAK AND WHITE-OAK BLOCKS AT THE LABORATORY OF FOREST PATHOLOGY, MADISON, WIS.

During the spring of 1919 the writer performed several series of experiments at the Madison laboratory to determine the efficiency of steam at atmospheric pressure in destroying mold and sap-stain fungi in artificially infected red or white oak blocks $2\frac{1}{2}$ by $2\frac{1}{2}$ by 10 inches. Incidentally the rate of drying and the amount of checking were noted in connection with the steaming.

The blocks were sawed from the sap-wood of summer-cut logs, weighed, and then sprayed with a water suspension of spores taken from cultures of mold fungi originally derived from infected material sent in by the writer. A list of the fungi used in these experiments follows:

Aspergillus flavus.
Aspergillus niger.
Cephalothecium roseum.
Ceratostomella sp.
Citromyces sp.
Graphium sp.
Monilia sitophila.
Mucor sp.
Penicillium asperulum.
Penicillium divaricatum.
Penicillium luteum.
Penicillium pinophilum.
Penicillium rugulosum.
Syncephalastrum sp.
Trichoderma sp.



FIG. 10.—Square billets close piled in a box car. This type of raw stock suffers considerably when piled in the manner shown here. Stripping or cross piling while in transit or storage is essential if losses from fungi are to be avoided.

The sprayed blocks were then placed in a tile chamber, which served as an incubator. After several weeks in this chamber, where an average relative humidity of 95 per cent and an average temperature of 70° F. prevailed, the blocks became well infected and developed countless numbers of the fruiting bodies peculiar to the fungi mentioned above (Pl. II, fig. 1).

A steam box was constructed of cypress, equipped with thermometers, dew-point apparatus, and manometer and connected with the main which supplies steam to the laboratory greenhouse (figs. 15 and 16). By means of suitable reducing valves in the connecting pipes it was possible to control the steam pressure in the box; hence, the

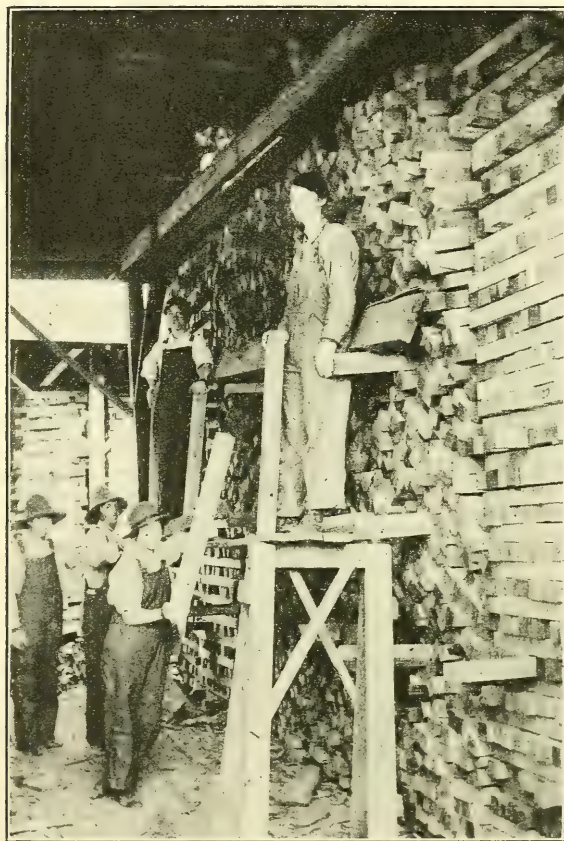


FIG. 11.—Stacking sawed billets in an open shed. It will be observed that the billets at the extreme right are cross piled, while those in the center are close piled. The former method of piling insures a better ventilation of the stack, provided intervals of at least 1 inch are left between the adjacent billets of a course. In the case of the cross-piled billets shown here this provision was not made.

exact conditions to which the blocks were subjected could be readily determined. Steam at atmospheric pressure only was used.

Previous to steaming, the blocks were again weighed. They were then close piled or stripped in groups of 25 in the steam box and steamed for different lengths of time. At the end of the steaming period, some of the lots were allowed to cool for a certain time and then reweighed. Others were weighed immediately. Nearly all were put in a small ventilated box in the open and allowed to air-dry for several weeks. Some, however, were placed in a closed shed for four weeks, and still others were taken

from the steam box, weighed, and placed directly in the tile chamber. Some lots were stripped; others were close piled. An interval of at least 3 inches was maintained between adjacent piles.

After the preliminary seasoning mentioned above, a number of the blocks were returned to the tile chamber for incubation. This was done for the purpose of subjecting the blocks to the conditions existing in box cars and poorly ventilated warehouses during warm and

sultry weather. The tile chamber, when given a preliminary treatment, which consisted of intermittent steaming for three successive days to reduce the amount of viable fungous growth therein, provided these conditions admirably. In this chamber the temperature was maintained at an average of 85° F., while the relative humidity varied from 70 to 95 per cent. At the end of four weeks in the tile chamber the blocks were removed and their condition with respect to molding noted.

The following observations were made from several series of experiments:

The amount of drying which took place in the steam box was comparatively slight. This seemed to depend, however, upon the relative moisture content of the wood previous to steaming. Green blocks usually lost, while partly seasoned blocks often gained in weight.

Beyond a certain length of time, dependent upon the moisture content of the wood and the surface area of the blocks in relation to volume, there seemed to be little gained, in so far as the reduction in weight was concerned, by continued steaming. Six or nine hours' steaming seemed to be no more efficient than three hours in the case of the 2½ by 2½ by 10 inch blocks.

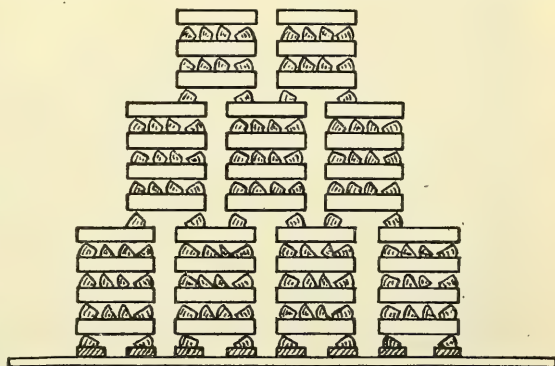


FIG. 12.—Diagram illustrating one method of stacking green split billets. This method is used by one of the large wheel factories of the North. When ample storage space in well-ventilated sheds is available, this method is recommended.

Steamed blocks subsequently dried more rapidly than those that were simply air-dried.

Open piling or stripping in the steam box was preferable, in that it permitted a better circulation of the steam in the box and thus insured a more uniform treatment of the blocks.

The amount of checking varied in the several lots when steamed under the same conditions. This may have been due to the fact that the blocks differed considerably in the relative proportion of sapwood and heartwood present.

The greatest amount of checking occurred in those lots that were subjected to rapid cooling and surface drying by exposure to air currents from open doors and ventilators. Blocks allowed to cool in the steam box with doors closed seemed to suffer least in this regard. Slow cooling was, in some cases, brought about by opening a small hatch in the roof of the steam box at the conclusion of the steaming period.

The total amount of checking which had taken place in the steamed blocks, both during the steaming process and the subsequent period of air seasoning, extending over four months, exceeded but little that noted in those blocks which had been simply air seasoned for the same length of time.

Steaming seemed to be effective in killing the fungi in the infected blocks when employed for a period of three hours. Cultures taken from various points

in or upon the blocks by means of a sterile scalpel and needle gave no growth, while cultures taken from check blocks which had not been steamed gave positive results in every case.

Steamed material, unless open piled under conditions which insured an ample supply of circulating air, molded almost as readily as green stock.

Steamed blocks that were given a month's air drying subsequent to steaming and previous to storage under the extreme conditions that prevailed in the tile chamber showed a little more resistance to the invasion of fungi than those blocks that were placed in the tile chamber immediately after steaming.

It is quite probable that the steam treatment of wood stock, followed immediately by prolonged submersion of the material in some of the antiseptic solutions to be described later, might prove to be a



FIG. 13.—Boards of red gum loaded on a truck and ready to be rolled into the preparator (shown in fig. 14).

fairly effective method for the control of fungi in infected stock. This treatment might be applied to special classes of wood stock where the margin of profit would justify the extra cost.

THE CHEMICAL TREATMENT OF GREEN WOOD STOCK.

Many attempts have been made to find some chemical compound or mixture that, when applied as a dip, will control sap-stain and mold in green timber. A great many substances have been tried, but none have proved entirely satisfactory. Under conditions not particularly favorable to the growth of fungi, several have met with considerable success. On the other hand, if the conditions were stimulating to fungous growth, the same substances often failed. Some treatments depend for their efficiency upon the neutralization of the acids in the wood and, at the same time, the establishment of

alkaline conditions. To this group belong sodium carbonate, sodium bicarbonate, sodium hydroxid, lime, and borax. Others are intended to poison the food of the fungi, and comprise such compounds and mixtures as mercuric chlorid, copper sulphate, sodium fluorid, creosote, and many other substances.

Toxicity tests (Humphrey and Fleming, 24)²⁰ conducted at the Madison laboratory upon a few molds commonly occurring upon infected timber, as well as upon several wood-destroying fungi, have clearly demonstrated that when the entire culture medium is permeated with these and many other preservatives, often in very small amounts, the growth of the fungus can be readily inhibited. Hence,

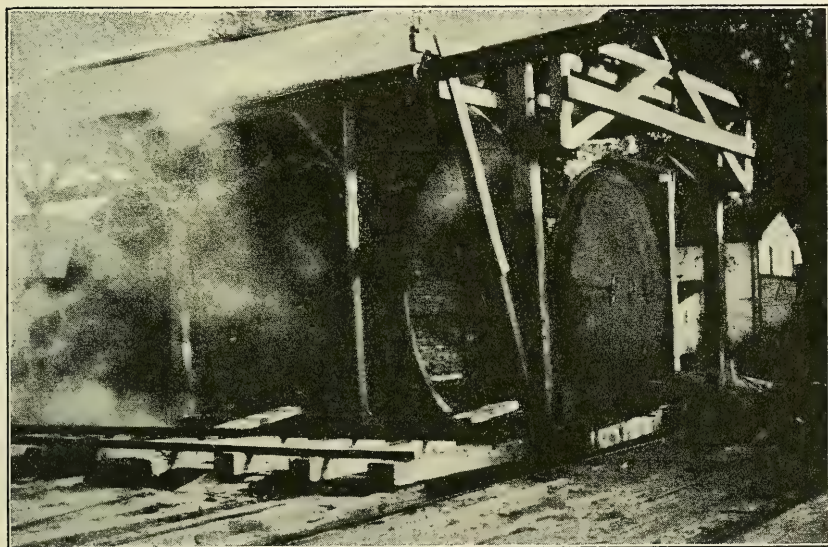


FIG. 14.—Preparator used for the commercial steaming of red-gum lumber at one of the mills in Arkansas.

if wood be thoroughly impregnated with a solution of one of these common preservatives it will be protected from decay as well as from sap-stain and mold.

This is quite possible in the case of thoroughly seasoned timber impregnated with preservatives by subjection to high pressure in closed retorts. The penetration of green timber by cold solutions of salts in an open tank or by the brush treatment, however, is extremely slight.²¹ Tests made by the writer for the presence of copper in the interior of $\frac{3}{4}$ by $\frac{3}{4}$ by $1\frac{1}{2}$ inch blocks sawed from the green

²⁰ Information also obtained from unpublished reports of toxicity experiments performed by Miss C. Audrey Richards at the Laboratory of Forest Pathology, Madison, Wis.

²¹ For a description of the pressure, open-tank, and brush treatments, the reader is referred to Forest Service Bulletin No. 78 (45) and to Farmers' Bulletin 744 (26), U. S. Department of Agriculture.

sapwood of red oak and then dipped for 10 seconds in solutions of copper nitrate and copper sulphate at ordinary temperature showed that these solutions had penetrated the ends of the blocks for a distance less than 5 millimeters (one-fifth of an inch) and scarcely a measurable amount in the case of the tangential or radial surfaces. It is evident, then, that whatever value there is in the use of cold dipping solutions lies entirely in the superficial coating of the preservative left upon the wood. Provided this is not brushed off or washed off by rain, it may inhibit or prevent the germination of fungous spores which happen to fall upon such surfaces. Hot solu-

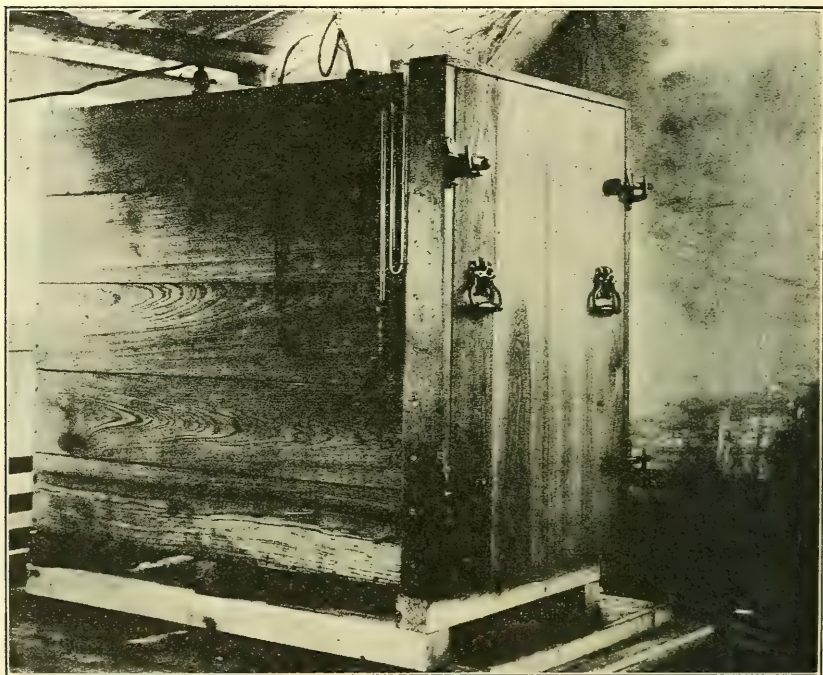


FIG. 15.—Steam box of cypress used in the experimental steaming of red-oak and white-oak blocks at the Madison laboratory.

tions, in that they tend to prevent the collection of bubbles of air upon the surface of the wood, probably give a more uniform distribution of the preservative over the dipped material. As far as penetration is concerned, however, it is doubtful whether the hot solutions, as ordinarily employed, possess any very great advantages. A slightly increased penetration may be secured by first subjecting the stock to a thorough steaming or by heating it for some time in a hot solution of the preservatives, as in the open-tank process. The air within the cavities of the wood is thereby expanded, and some escapes. Provided the steamed or hot wood is at once transferred to a cold solution of the preservative and there allowed to remain till

cool, an amount, approximately equal to the original volume of the escaped air, will be forced into the wood. This is a slow process, however, and therefore somewhat expensive.

The rate of evaporation of the liquid, in the case of hot solutions, is much greater than in cold solutions; hence, it becomes necessary to take frequent hydrometer readings of the bath and to make the proper adjustments in the relative proportions of the solvent and dissolved substances in order to maintain a uniform concentration.

Dipping may be of some value when applied to stock free from fungi. In those cases where the fungi are already in the timber, however, it is doubtful whether very much good can result from chemical dips unless the material be subjected first to a relatively high temperature and for a length of time sufficient to destroy these organisms.

The salts used in the chemical treatment of lumber are likely to vary considerably in strength and purity. It is probable that the lack of uniformity in the results obtained by different investigators when employing nominally the same compounds may be traced partly to this cause. A few of the preservatives commonly used are described here.

SODIUM CARBONATE AND SODIUM BICARBONATE.

The substances which have been most frequently employed to prevent sap-stain in lumber are sodium carbonate (commonly in the form of soda ash) and sodium bicarbonate (baking soda). Solutions of these salts are applied either hot or cold by dipping in an open tank. On southern yellow pine, when used in concentrations of 4 to 5 per cent sodium carbonate and 5 to 6 per cent sodium bicarbonate, these

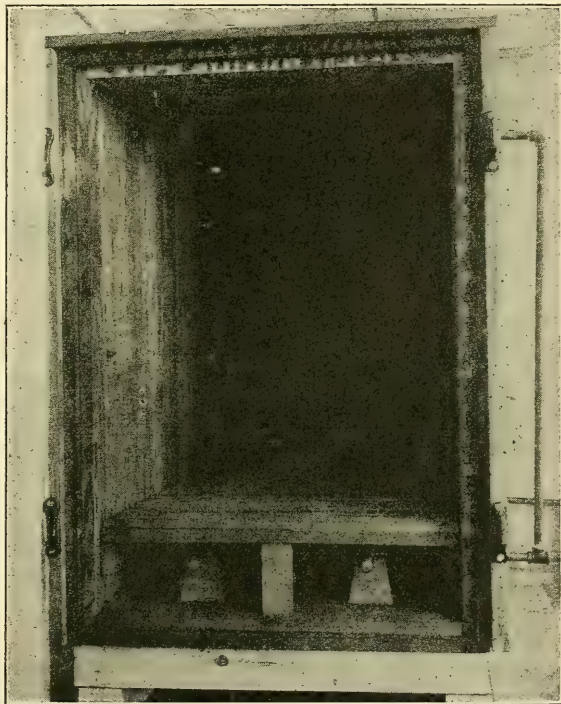


FIG. 16.—Details of the interior of the steam box used in the experimental steaming of red-oak and white-oak blocks at the Madison laboratory.

substances have given more or less satisfactory results (Weiss and Barnum, 57). In wet weather, however, it has been found necessary practically to double the strength of the solutions. Moreover, both sodium carbonate and sodium bicarbonate cause a yellow to brown discoloration of the wood. Lumber treated with these preservatives must be open piled or it may mold and stain badly during warm, humid weather.

A good grade of sodium carbonate in the form of soda ash should contain $58\frac{1}{2}$ per cent alkali, while the amount present in sodium bicarbonate (baking soda) is about 37 per cent. Solutions of the latter are more or less decomposed at temperatures above 158° F., giving off carbon dioxid. In a series of laboratory experiments followed by practical field tests on southern yellow pine and red gum, Rumbold (37) found that the blue-stain fungus is sensitive to alkalis but not to acids, that an 8 per cent solution of sodium carbonate is as effective as an 11 per cent solution of sodium bicarbonate, and that the amount necessary to prevent growth varies with the substratum. Freshly cut sapwood of southern yellow pine or red gum required 8 per cent sodium carbonate and 10 per cent sodium bicarbonate solutions under conditions which were especially favorable for the growth of the blue-stain fungus. In dry weather a weak solution of the alkali (a 5 per cent solution of sodium carbonate and a 4 per cent solution of the bicarbonate) kept the yellow pine boards free from stain. It was also observed that the spores of the blue-stain fungus are more resistant than the mycelium. These experiments seem to show that sodium carbonate and sodium bicarbonate possess some value as a preventive against sap-stain but that the success attending the treatment is largely dependent upon weather conditions.

SODIUM FLUORID, SODIUM BIFLUORID, AMMONIUM FLUORID.

Sodium fluorid, which has proved to be very toxic to wood-destroying fungi (Teesdale, 49), has also been tested to determine its toxic properties in connection with the blue-stain fungus. Representatives²² of the Forest Products Laboratory, working independently and in cooperation with certain lumber mills located in Mississippi and Louisiana, found that both sodium fluorid and sodium bifluorid were effective against sap-stain. The fluorids have an advantage over sodium carbonate and sodium bicarbonate in that they do not discolor the timber. One of these investigators, in a comparative series of experiments with a number of preservatives, including $2\frac{1}{2}$ per cent sodium fluorid, $2\frac{1}{2}$ per cent sodium bifluorid, and $2\frac{1}{2}$ per cent ammonium fluorid, found that in the concentrations mentioned these salts were fairly effective against sap-stain. The ammonium fluorid,

²² Unpublished reports by Pettigrew and Knowlton in the files of the Forest Products Laboratory, Madison, Wis.

in addition, seemed to be of some value in controlling mold. However, both of these series of experiments were performed during hot and dry weather—conditions unfavorable to fungous growth; hence, it is impossible to draw satisfactory conclusions from the results.

While the fluorids may be effective in controlling decay and, to a certain extent, stain-producing organisms, they can not be depended upon to prevent molding.

MERCURIC CHLORID.

Probably the best antiseptic to prevent sap-stain and mold in green wood stock is mercuric chlorid. When used on coniferous woods and on many of the hardwoods in concentrations of 0.1 per cent to 1 per cent, it has been found to be exceedingly efficient. The addition of 0.1 to 1 per cent hydrochloric acid is said to increase its stability. Mercuric chlorid, however, is extremely poisonous when taken internally. Many individuals show a marked susceptibility to the poison even when applied externally. Moreover, the solutions of mercuric chlorid are corrosive to iron, zinc, and many other metals commonly employed in dipping vats. For these reasons it can not be recommended for general use.

SOME RESULTS OBTAINED FROM THE USE OF ANTISEPTICS BY VARIOUS INVESTIGATORS.

It is probable that the efficiency of a given antiseptic varies considerably when applied to woods of different species and at various stages of air seasoning. As stated before, the results are likewise dependent upon climatic conditions. On open-piled boards of shortleaf pine in Missouri, Von Schrenk, Bessey, and Spaulding found that 5 per cent sodium bicarbonate or one-twentieth per cent mercuric chlorid gave good results (Hedgcock, 20). On open-piled white pine in Wisconsin, the first two investigators found that the solutions giving the best results were 5 per cent borax and 2.5 per cent sodium bicarbonate, while on boards of Norway pine in open piles 5 per cent borax, one-twentieth of 1 per cent mercuric chlorid, and 2.5 per cent sodium bicarbonate were most effective (Hedgcock, 20). As the result of experiments on longleaf pine boards in open piles at Bogalusa, La., Weiss and Barnum (56, 57) concluded that the most effective antiseptics for the control of sap-stain, in that wood at least, are mercuric chlorid in concentrations of 0.1 to 1 per cent and sodium bicarbonate in strengths varying from 5 to 10 per cent. In these experiments 5 per cent borax gave poor results.

Hedgcock (20), in connection with certain experiments at Baltimore, Md., on the prevention of mold and stain in veneer baskets made from poplar, sycamore, beech, gum, and maple, found that the most effective solutions were 10 per cent sodium carbonate, 6.5 and 10 per cent sodium bicarbonate, 2.5 per cent sodium bicarbonate plus

0.66 per cent borax and boric acid, 0.20 per cent sulphur plus 0.20 per cent lime, 0.10 per cent mercuric chlorid plus 0.20 per cent hydrochloric acid, 10 per cent potassium (alum), and 0.33 per cent phenol salicylate. He concludes that of these substances, 5 to 10 per cent sodium bicarbonate is the safest and best to use.

In nearly all the cases cited the antiseptics proved to be of some value in preventing the growths of the sap-stain fungus. Molds, however, are extremely resistant to chemical treatment and consequently are difficult to control. To quote from Lafar (28): "Whether the waterproof character of some cell membranes, e. g., the conidia of *Penicillium* and *Aspergillus*, should be attributed to



FIG. 17.—Barrels and steam-coil connections as used in the experimental dipping of red-oak spokes at one of the large spoke mills in the South.

the deposition of excreted fatty or waxy substances must be left undetermined. Biologically this phenomenon is important, since it prevents the penetration of toxic substances from the aqueous medium and thereby also opposes the attempts of the mycologist to kill such fungi by means of aqueous toxic solutions." Since, as has been stated repeatedly, molds develop largely on the surface of the timber and are sufficiently removed during the several finishing processes to which the timber is sooner or later subjected, their presence in most cases should occasion but little concern in connection with vehicle stock.

EXPERIMENTAL DIPPING OF RED-OAK SPOKES.

DIPPING.

In July, 1918, several series of experiments were performed by the writer in cooperation with one of the large spoke mills of the

South. It was desired to test in a more practical way some of the antiseptics that had been used on a small scale during preliminary experiments at the Madison laboratory. In these experiments first-grade escort spokes $2\frac{1}{2}$ by $2\frac{1}{2}$ by 27 inches long of red oak were used. They were selected mainly for two reasons: First, red oak in a green condition was the wood, of all those used at this particular mill, which seemed to be the most liable to mold and sap-stain; second, the escort spoke was convenient to handle in connection with the dipping apparatus employed.

All spokes were taken directly from the warehouse after turning and grading. It was noted that 80 to 90 per cent of them contained sapwood varying in amount from 5 to 100 per cent.

In lieu of dipping tanks it was decided to use whisky barrels of 50-gallon capacity. Three of these were placed on a platform in the mill yard beside the tracks upon which the trucks were operated. One barrel was equipped with a steam coil of bent $\frac{1}{2}$ -inch iron pipe provided with shut-off valves (fig. 17). This coil, when connected with the main steam boiler, supplied the necessary heat for maintaining the temperature of the dipping solutions. A piece of corrugated, galvanized-iron plate, approximately 2 by 6 feet, when supported in a slanting position with the lower end resting upon the top of the barrel, served as a drain board. Iron tongs similar to those used by blacksmiths, hydrometers, thermometers, and a gallon measure completed the list of essential apparatus.

The following antiseptics were applied in the form of solutions or in a dry state:

- (a) Barrett's grade 1 liquid creosote, 10 per cent by volume.
Perfection kerosene oil, 90 per cent by volume.
Temperature, 80° to 90° F.
- (b) Barrett's grade 1 liquid creosote, 10 per cent by volume.
Perfection kerosene oil, 90 per cent by volume.
Temperature, 150° to 155° F.
- (c) Powdered borax, 5 per cent by weight.
Water, 95 per cent by weight.
Temperature, 80° to 90° F.
- (d) Mercuric chlorid (C. P.), 1 per cent by weight.
Hydrochloric acid (commercial), 1 per cent by weight.
Water, 98 per cent by weight.
Temperature, 80° to 90° F.
- (e) Dry salt (finely grained).
- (f) Dry quicklime (finely powdered).

The spokes were conveyed to the dipping barrels on trucks. There they were grasped by means of the iron tongs, immersed from 5 to 10 seconds in the bath, and then placed on the corrugated-iron drain board (fig. 18). When practically all of the excess liquid had drained off they were again grasped with the tongs, loaded upon another truck, and wheeled to the north end of one of the open sheds

in the yard. There they were unloaded, close piled, and allowed to remain until ready for shipment.

During the dipping operation it was observed that in some cases as many as 10 to 15 per cent of the untreated spokes in a given truck load showed the presence of sap-stain. In one lot the number showing sap-stain and mold was estimated at 50 per cent. Other lots were practically free from fungi. During the experimental work the weather was for the most part hot and dry. Following one or two light showers the amount of mold on untreated material showed a marked gain.

The methods of dipping were similar for all baths except in the case of the hot creosote. Here, the steam coil was employed and a

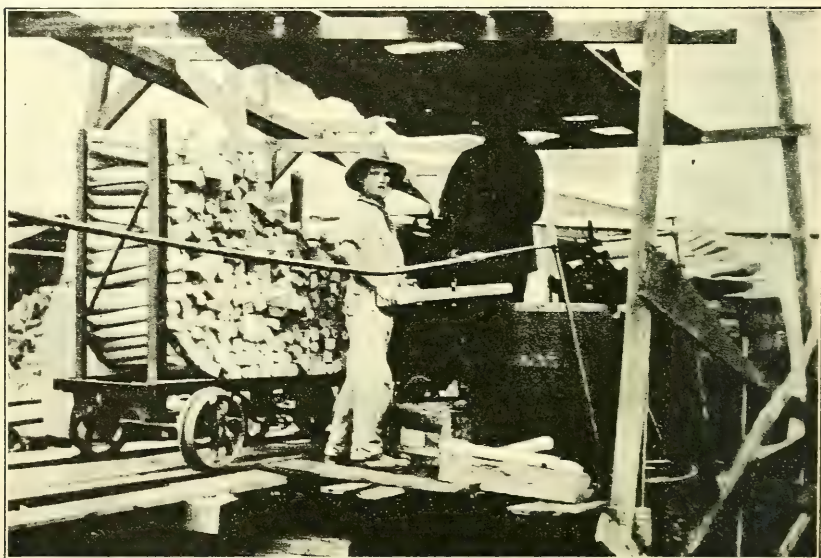


FIG. 18.—The experimental dipping of red-oak spokes green from the lathe.

temperature of 150° to 155° F. maintained. One barrel served for both cold and hot creosote. The borax was dissolved by aid of the steam coil in the second barrel. A third barrel was necessary for the mercuric-chlorid dip. Thermometer and hydrometer readings were taken at frequent intervals, and whenever necessary corrections were made to maintain a constant temperature and concentration in the bath.

Incidentally, it was noticed that ambrosia beetles were very quickly killed by the creosote dip, a point of importance to consider in controlling insect pests which at times, especially during warm and damp weather, are said to cause considerable losses in piled lumber.²³ (Weiss, 56, p. 18-20.)

²³ A certain species of beetle, *Dendroctonus ponderosae* Hopk., has been mentioned by Von Schrenk (41) as being partly responsible for the dissemination of the spores of the blue-stain fungus.

Both cold and hot solutions of creosote may cause considerable irritation, and in some cases blistering, when brought in contact with the skin. By proper use of the tongs, however, this trouble was avoided. Rubber gloves were worn during the dipping of spokes in the solutions of mercuric chlorid, since that salt, as already stated, is a deadly poison when taken internally and is sometimes absorbed through the skin when solutions are handled continuously.

Many metals, such as iron and zinc, possess the common property of precipitating metallic mercury from the solutions of its salts. For this reason the iron tongs and other metallic objects could not be used in connection with the mercuric-chlorid dip.

The spokes that were treated with salt or lime were placed, a few at a time, in wooden boxes containing the respective substances in a finely powdered state and were rolled to distribute the chemicals over them as evenly as possible. The excess was shaken off. They were then close piled in one section of the warehouse. After 24 hours the lime coating showed a marked tendency to absorb moisture and cake. Moreover, it turned the wood dark. For this reason the liming was discontinued after 300 spokes had been treated. The salted spokes soon became exceedingly moist, due to the hygroscopic nature of the salt. The antiseptics used and the number of spokes treated in the different lots follow:

(a) 10 per cent creosote in kerosene, cold.....	5,100
(b) 10 per cent creosote in kerosene, hot.....	5,100
(c) 5 per cent borax in water.....	1,013
(d) 1 per cent mercuric chlorid plus 1 per cent hydro- chloric acid.....	1,000
(e) Dry salt.....	1,032
(f) Dry quicklime.....	300

The first lot went forward in a box car loaded to capacity with 5,000 cold-creosoted spokes, 5,000 that had been hot creosoted, 800 spokes that had been dipped in mercuric chlorid, and 350 that were untreated. It was originally intended to ship the other lots at the same time. The car, however, was found to be too small, so the borax-treated, salted, and limed spokes went forward at a later date.

Many of the cold-creosoted spokes that had lain in the shed for two to three weeks awaiting shipment were slightly molded. It was noticed that those with the mold were taken from that part of the pile that had suffered most from poor ventilation, namely, near the bottom and in the rear. The spokes in the other lots at that time seemed to be free from mold or sap-stain.

METHOD OF LOADING CAR NO. 1.

The spokes were stacked in transverse ricks, beginning at the end of the car and working toward the doorway. Each rick was built up in the following manner. A row consisting of five pairs of spokes

all parallel to the length of the car was laid across the floor. An interval of perhaps 1 or 2 inches separated the members of a pair, and the distance between successive pairs was made a little less than the length of a spoke. Upon either end of these was laid a single transverse row of spokes. A third layer similar to the first and a fourth similar to the second were then laid down. With two more alternate layers a comparatively open base six layers in height and providing for partial aeration of the ricks was constructed. Upon this base the remaining spokes of the rick were close piled in successive layers, two or three spokes in depth. Each alternate horizontal layer was placed at a slight angle to those directly above and below, but all had a general direction lengthwise of the car. Each rick when built to within 2 feet or so of the roof contained on an average 833 spokes. As soon as one end of the car had been filled ricks were placed in the opposite end. In the doorway three longitudinal ricks were constructed and any space remaining was filled in with loose spokes. In this particular case one end of the car was stacked with the hot-creosoted spokes, the opposite end and $1\frac{1}{3}$ ricks in the doorway being stacked with the cold-creosoted spokes. Parts of two ricks in or near the doorway comprised spokes treated with mercuric chlorid, and the remainder consisted of untreated spokes thrown in loosely between the longitudinal ricks and the doorway. Both doorways were boarded up with 6-inch boards spaced $1\frac{1}{2}$ inches apart, and both doors were left open for about 1 foot. This car left the yard on July 24, consigned to one of the large vehicle factories of the North and reached its destination on August 14. On August 15 and 16 it was unloaded and inspected by C. J. Humphrey and the writer. During the time that the car was in transit the weather was in general hot and dry, although local showers may have been encountered.

CONDITION OF SPOKES IN CAR NO. 1 UPON ARRIVAL AT DESTINATION.

The inspection at the time of arrival was very thorough, each spoke being handled separately and a record kept of the number showing mold in any degree. Observations were also made, in a general way, of the extent of sap-stain and incipient rot. No attempt was made to discriminate between heavy and light infections, as these largely depended, with a given preservative, on the position of the spokes in the ricks or in the car with respect to the amount of ventilation received. In general, the top layers to a depth of 15 to 18 inches showed very little mold; likewise, the loosely arranged bases were quite free or comparatively so. The molds consisted for the most part of fluffy white to tawny mycelium, together with a comparatively small amount of green *Penicillium*. In the case of the cold-creosoted spokes, there seemed to be an increase over the amount

which was observed on the same spokes at the time of loading. For convenience in presentation, the data relative to location in the car and condition are given in Table I.

TABLE I.—*Condition of the red-oak spokes in car No. 1 upon arrival at its destination.*

Location in car. ^a	Antiseptic.	Condition.	Percentage molded (based on 833 spokes per rick).
Forward end of the car:			
Loose in the doorway.	Untreated.....	Free from mold or sap-stain; a few badly checked.	.....
Stacked in the doorway and first rick.	Mercuric chlorid and hydrochloric acid.	None with mold or sap-stain; not so many checked as in the untreated lot.	.....
First rick.....	Hot creosote at 150° to 155° F.	None with mold; no sap-stain.....	.....
Second rick.....	do.....	68 with mold; no sap-stain.....	8.2
Third rick.....	do.....	431 with mold; no sap-stain.....	51.7
Fourth rick.....	do.....	277 with mold; no sap-stain.....	33.2
Fifth rick.....	do.....	218 with mold; no sap-stain.....	26.2
Sixth rick (end of the car).	do.....	222 with mold; no sap-stain.....	26.7
Opposite end of the car:			
Stacked in the doorway and first rick.	Cold creosote at 80° to 90° F.	69 with mold; no sap-stain.....	8.3
Second rick.....	do.....	492 with mold; no sap-stain.....	59.1
Third rick.....	do.....	348 with mold; no sap-stain.....	41.8
Fourth rick.....	do.....	207 with mold; no sap-stain.....	24.8
Fifth rick (end of the car).	do.....	142 with mold; no sap-stain.....	17.0

^a Ricks are in each case numbered from the first transverse rick on either side of the area between the doors and extending back to the ends of the car.

It will be seen from Table I that the spokes that were placed in the doorway where better ventilation could be had did not mold or sap-stain. Those that were the most exposed, however, were inclined to suffer from checking. The largest proportion of molding took place in the second or third ricks, but in no case was this accompanied by sap-stain, and in no instance was it severe enough to necessitate culling. The considerable reduction in the fourth and fifth ricks, which was most marked in the rear end of the car, is difficult to explain. In the forward end, the motion of the train caused the last rick to slide away from the end of the car, and thus somewhat improved the ventilation. It is possible, then, that in the rear end the tendency of the mass of spokes to surge backward and forward whenever the continuous passage of the car was interrupted, together with the fact that a hole existed in the bottom of the car due to the breaking of a floor plank, may have provided sufficient ventilation to account for the low percentage of mold in the fourth and fifth ricks.

It was noted that the stage in the development of the mold on the creosoted material was an early one, namely, a white, fluffy mycelium, which in most cases had not advanced to the spore-producing condition. This indicates a retarding effect due to the treatment. It is

also evident that the creosote, though unable entirely to control the mold, seemed to prevent the development of sap-stain. From the evidence it would also appear that heating the creosote to 150° or 155° F. does not increase its effectiveness to any marked degree, the difference in the percentage of moldy spokes in the two treatments being less than 1 per cent.

METHOD OF LOADING CAR NO. 2.

The second car, containing 1,032 salted, 1,013 borax-treated, 300 lime-treated red-oak, and the remainder untreated, white-oak escort spokes, was loaded on August 3 and 5.



FIG. 19.—“Ricking,” or stacking, treated escort spokes in a box car (car No. 2).

Those spokes that had been salted were exceedingly moist, owing to the hygroscopic property of the salt. On many of these species of *Penicillium* were found. The limed spokes were dark in color and in a few cases seemed to be developing sap-stain. The borax-treated spokes were apparently quite free from fungi.

The method used for stacking the spokes in the second car differed somewhat

from that in the first. The base of each rick was constructed in the same manner, though of four instead of six layers. Upon this base the spokes were carefully stacked, using two 1½-inch by ¼-inch crossers of elm between successive layers (fig. 19). Each rick held on an average 840 spokes. The doorways were closed in the same manner as in car No. 1. This consignment left the yard on August 6 and arrived at the same factory located in the North on August 20, a period of two weeks in transit. During this time the weather was hot and comparatively dry.

CONDITION OF SPOKES IN CAR NO. 2 UPON ARRIVAL AT DESTINATION.

On August 21 the spokes were unloaded and inspected by C. J. Humphrey and the writer. Table II gives the location of the different lots and their condition upon arrival.

TABLE II.—Condition of the spokes in car No. 2 upon arrival at its destination.

Location in car.	Material.	Antiseptic.	Condition.	Percentage molded (based on 840 spokes per rick).
Ricks in the end of the car containing treated spokes:				
First rick	White oak	Untreated	147 moldy; a few sap-stained	17.5
	do.	A few untreated layers at top	1 moldy	.1
Second rick	Red oak	Remaining layers borax, 5 per cent.	67 moldy; many sap-stained.	7.9
	do.	Top layers borax, 5 per cent.	7 moldy; many sap-stained.	.8
Third rick	do.	Middle layers lime	4 moldy; some sap-stained.	.4
	do.	Spokes very dark in color		
Fourth rick	do.	Bottom layer salt	34 moldy; some sap-stained.	4.0
	do.	Salt	300 moldy; many with Penicillium in all parts of rick, badly damaged.	35.7
Fifth rick	White oak	Untreated	330 moldy; much sap-stain.	39.3
Sixth rick	do.	do.	292 moldy; much sap-stain.	34.8
Ricks in the doorway and in the opposite end of the car:				
In doorway	do.	do.	No mold; no sap-stain.	0
First rick	do.	do.	87 moldy; many sap-stained.	10.4
Second rick	do.	do.	312 moldy; many sap-stained.	37.1
Third to sixth ricks.	do.	do.	Not examined.	

The proportion of infected spokes, based on the total number in the different lots in the end of the car containing these spokes, is:

Untreated	29 per cent moldy.
Salted	32.3 per cent moldy.
Borax (treated)	7.3 per cent moldy.
Lime (treated)	1.3 per cent moldy.

These figures can by no means be used as a basis for an exact comparison of the values of the three preservatives. The location of the ricks in the car introduces another and very important factor. To note whether the hygroscopic property of the salt had a tendency to affect the humidity in the end of the car in which the salted spokes were stacked, thus influencing, perhaps, the amount of molding in adjacent lots, it was decided to observe the unloading of the spokes in the opposite end of the car. After two ricks had been unloaded, however, it became evident that this was not the case, as conditions in that end were practically the same as in the first. From the data derived, at least from this lot, given in Table II, it would seem that salt when applied dry to green spokes is of little value in controlling either sap-stain or mold. Lime, though effective in preventing both mold and sap-stain, yet because of its darkening effect on the wood and its tendency to form calcium carbonate, which cases over the surface and is said to dull the knives used in subsequent processes of manufacture, is debarred from further consideration. Borax, however, with 7.3 per cent moldy spokes, seems to be somewhat effective against mold, but of less value in controlling sap-stain.

SUMMARY OF OBSERVATIONS.

Creosote dipping seemed to prevent sap-staining, but it had little effect upon mold. In no way did it detract from the sale value of the spokes.

The creosote bath at 80° to 90° F. was nearly as effective as at 150° to 155° F.

Mercuric chlorid, 1 per cent, seemed to be very effective in controlling both sap-stain and mold.

Borax solution, 5 per cent, appeared to be somewhat effective in controlling mold, but of less value in regard to sap-stain.

The use of lime in the treatment of spokes was not satisfactory, on account of its darkening effect on the wood, the covering up of physical defects, and the probability of dulling the knives used in later processes of manufacture.

Salt sprinkled over the spokes was of no value in preventing either mold or sap-stain.

The ventilation of spokes in a box car is an important factor.

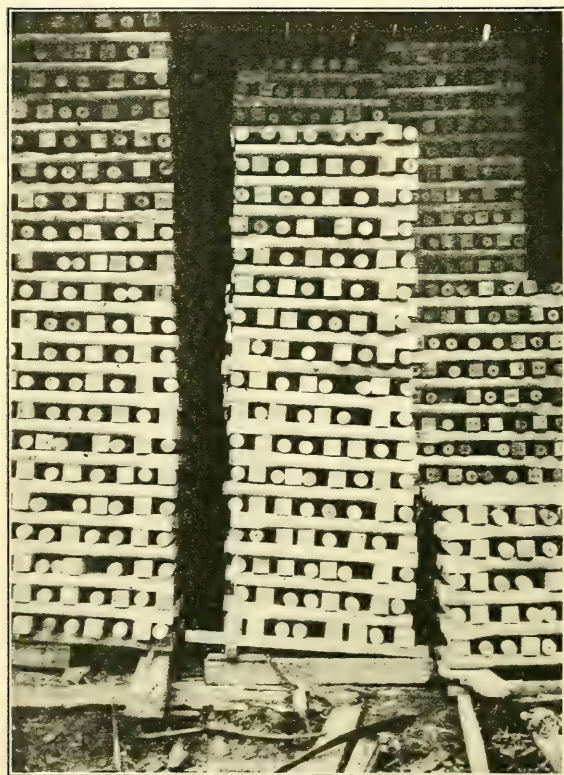


FIG. 20.—Green turned spokes cross piled in open or ventilated sheds. Green spokes are sometimes allowed to surface dry in this manner for one to two months preparatory to shipping in box cars.

Those spokes in the doorway, even if untreated, usually have but little tendency to mold or sap-stain.

Practically none of the spokes in either car were culled on account of defects due to fungi, although a few in the areaway between the doors were thrown out on account of slight checking.

No incipient decay was found in any of the material.

EXPERIMENTAL DIPPING OF RED-OAK BLOCKS AT THE LABORATORY OF FOREST PATHOLOGY, MADISON, WIS.

A comparison of the specific antiseptic values of the chemical substances employed in the spoke-dipping experiments can hardly be made, since these substances were not used in solutions of uniform strength. To determine, if possible, the comparative values of these and several other common antiseptics and preservatives in the control of mold and sap-stain fungi, several series of experiments were undertaken at the Madison laboratory. Where possible, solutions were made up to a calculated value of 1 per cent actual weight of anhydrous salt. The hygroscopic substances—sodium chlorid, calcium chlorid, and glycerin—were added in certain instances to determine whether or not they would increase the efficiency of the preservative by keeping the surface of the treated wood moist. A list of the substances used follows:

Alum (potassium).	Potassium chlorate.
Ammonium fluorid.	Sodium fluorid.
Bleaching powder.	Sodium bifluorid.
Borax.	Zinc silicofluorid.
Copper sulphate.	Creosote in kerosene.
Lead acetate.	Formalin.
Lead nitrate.	Lysol.
Magnesium silicofluorid.	Mykantin.
Mercuric chlorid.	Orthonitrophenol.
Mercuric chlorid and hydrochloric acid, 1 per cent.	Rongalite.



FIG. 21.—Storage of spokes in a warehouse. The truck spokes at the left have just been painted by girls with a resin-linseed oil mixture to prevent checking.

Red-oak blocks $\frac{3}{4}$ by $\frac{3}{4}$ by $1\frac{1}{2}$ inches long, sawed from the sapwood of summer-cut logs, were used in each case. Ten blocks constituted a group. The individual blocks of a group were immersed for approximately 10 seconds in one of the respective solutions, drained, and then sprayed on all six sides with a water suspension of the spores taken from the same cultures as those used in the steaming experiments.²⁴ The sprayed blocks of each group were then close piled and placed in the tile chamber mentioned on page 29. An in-

²⁴ See page 29 for the list of fungi.

terval of at least $1\frac{1}{2}$ inches was maintained between adjacent groups. In the tile chamber the blocks were subjected to a temperature averaging 80° F. and a relative humidity varying from 85 to 100 per cent. At the end of three to four weeks all blocks were carefully examined. The following observations were made at that time:

None of the preservatives was entirely effective in controlling mold when used in concentrations of 1 per cent.

Blocks dipped in sodium carbonate, sodium bicarbonate, sodium fluorid, sodium bifluorid, ammonium fluorid, magnesium silicofluorid, zinc silicofluorid, and bleaching powder became badly molded.

Potassium (alum), potassium chlorate, and copper sulphate seemed to stimulate all or certain species of the fungi used. The last seemed to incite the growth of *Aspergillus niger* in particular.

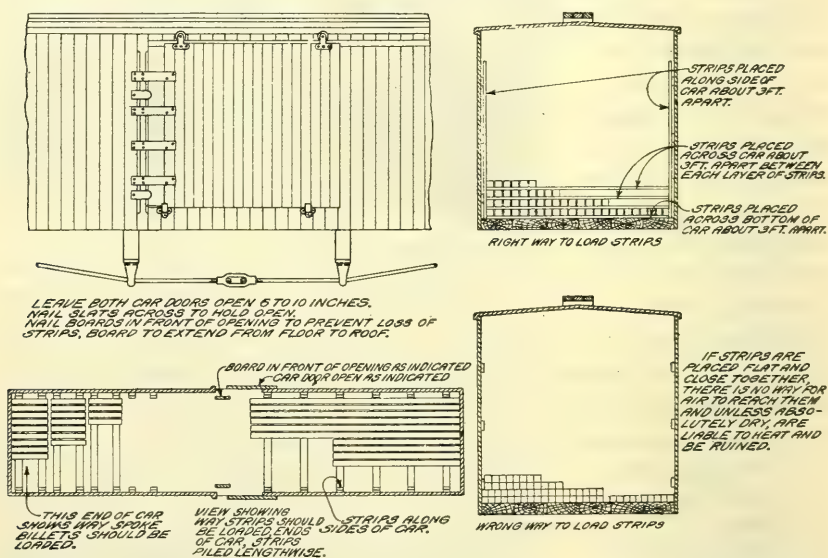


FIG. 22.—Diagram illustrating the method of loading used by one of the large wheel factories and recommended by the wood-stock committee in connection with vehicle stock.

Borax was effective in controlling the sap-stain fungus (*Ceratomyces* sp.). Though it did not entirely prevent the growth of mold, the amount of mold that did develop was very slight in comparison with that on the blocks treated with the other preservative solutions. Under these circumstances it compared favorably with 1 per cent mercuric chlorid.

The addition of the hygroscopic substances—sodium chlorid, calcium chlorid, and glycerin—to the solutions of the preservatives apparently did not increase their efficiency.

Of the organic compounds and mixtures tested here, creosote in kerosene gave the best results, while mykantin stood second. The latter, however, stained the wood yellow, a property which would prohibit its use for many purposes.

STORAGE OF GREEN DIMENSION, SAWED, OR TURNED STOCK AT THE MILL.

If it becomes necessary to store dimension or turned green stock without giving it the protection referred to, cross piling or stripping in properly ventilated sheds is absolutely essential (figs. 20 and 21). All strips should be narrow and at least three-fourths of an inch, but preferably 1 inch, in thickness and should be thoroughly seasoned or given some antiseptic treatment.

HANDLING GREEN DIMENSION, SAWED, OR TURNED STOCK IN TRANSIT.

If it becomes necessary to ship green dimension, sawed, or turned stock and planks during the late spring and summer months, attention must be paid to the cleanliness and ventilation of such material while in transit.²⁵

Cattle, vegetable, or ventilated box cars which have been previously cleaned are to be preferred for small stock. In ventilated box cars the end doors should be cleated open. If only box cars of the ordinary type are available, the material should be piled according to methods similar to the one shown in figure 22. In the case of spokes and sawed billets, a cross-piled foundation, four to six courses high, is recommended in addition to the directions given (figs. 23 and 24).

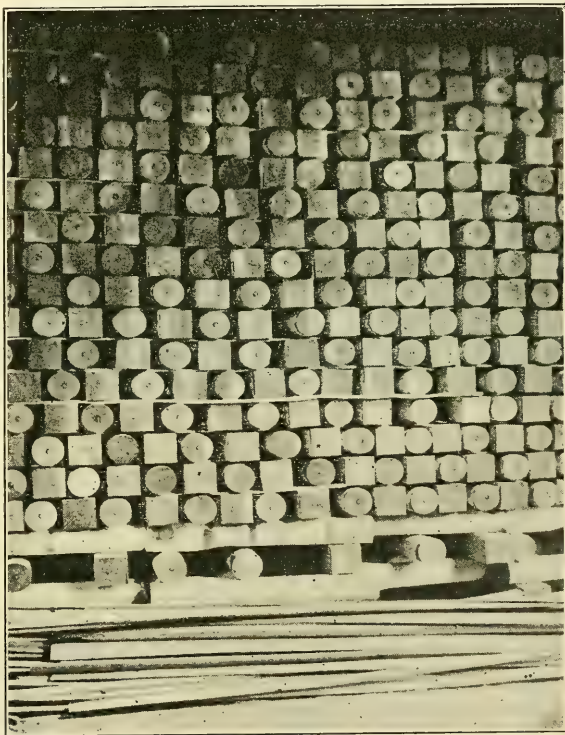


FIG. 23.—Artillery spokes "ricked" in a box car. Elm strips one-half inch by $1\frac{1}{2}$ inches used between the courses.

When doors of box cars are loosely boarded up (fig. 25) or cleated open (figs. 9 and 22), it is recommended that they be spiked, that the bill of lading bear an indorsement to the effect that the doors were left open and cleated at the request of the shipper, and finally that

²⁵ The directions given under "Provisions for the proper ventilation of stock in transit," page 23, apply here.

a notice similar to that devised by one of the wheel companies and cited in Bulletin No. 30 of the wood-stock committee²⁶ be nailed to the car, reading as follows:

TAKE NOTICE.—DO NOT CLOSE DOORS.—The lumber in this car is green and is carefully cross piled that there may be good circulation of air through the stock. The doors are left partly open and cleated by the shipper upon request of the consignee. If the doors are closed the stock will be liable to damage in transit.

Should this car break down in transit, making it necessary to transfer the stock to another car, it should be stacked in the car in the same manner and doors left open in the same way.

The use of box cars is usually demanded by those in charge of bending mills where green rim stock is to be shipped. These cars



FIG. 24.—Artillery spokes "ricked" in a box car. A cross-piled base, strips, and open-boarded doorway are important details in the provision for proper ventilation of the stock while in transit.

expose the stock to less damage from checking. Unless attention is paid to stripping or some method of piling so as to insure ventilation, however, molding and sap-staining may result. One method used for the piling of rim strips in cars is shown in figure 26.

SUMMARY.

It is evident that the prevention of sap-stain, mold, and incipient decay in green material, and in vehicle stock in particular, lies in a combination of remedial factors, the following being especially important: Care in the selection of raw stock in order to obtain, if possible, material free from fungous infections; expedition in the movement of raw stock from the felling of the logs to that time in the process of manufacture when the material becomes sufficiently dry to resist the attacks of fungi; provision at all times for ample ventilation of the stock that it may quickly become at least surface dried, thus making it difficult for the fungous spores to obtain from the exposed sapwood the moisture necessary for germination;

²⁶ National Implement and Vehicle Association and other Vehicle and Vehicle Parts Manufacturers. Information Division of the Wagon and Vehicle Committee and the Wheel Manufacturers' War Service Committee. Wood Stock Committee. Sap-stain and mold in transit. Nat. Implement and Vehicle Assoc., etc., Bul. 30, 5 p. 1918. A. B. Thielens, chairman. Typewritten.

the kiln drying of the stock wherever possible and whenever the cost will permit; and in special cases steam treatment or the use of anti-septic dips, followed by proper piling to insure ample ventilation.

It must be continually borne in mind that none of these is by itself a sovereign remedy. Preservative dips or steam treatment were not in themselves, under the emergency manufacturing conditions incident to the war, by any means sufficient to control molding of green stock when close piled in storage warehouses or while in transit in box cars.

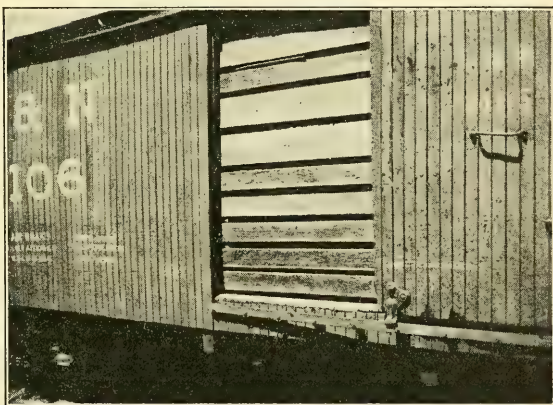
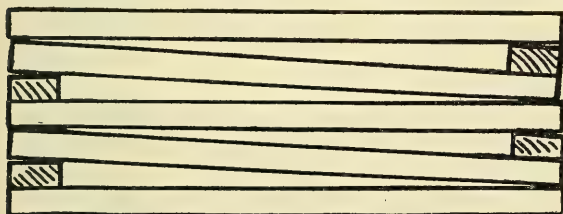


FIG. 25.—A box car loaded with spokes and ready for shipment. Spaces of $1\frac{1}{2}$ inches are left between adjacent boards nailed across the doorways to allow for ventilation of the stock while in transit.

In connection with this investigation, it should also be borne in mind that we are dealing with three distinct groups of fungi, namely, the molds, staining organisms, and true wood-destroying organisms, the antiseptics being more efficient against the last two groups than



the first. As far as is known, neither molds nor staining fungi cause any appreciable diminution in the strength of timber and hence are unimportant in vehicle manufacture from the standpoint of strength and probably durability. The staining fungi can be controlled to a certain extent by the intelligent use of antiseptics and possibly by steaming, and it seems reasonable, in the light of experience, to suppose that the development of wood-destroying fungi can also be prevented.

LITERATURE CITED.

- (1) ASO, KANJIRO.
1901. On the rôle of oxydase in the preparation of commercial tea. *In* Bul. Col. Agr., Tokyo Imp. Univ., v. 4, no. 4, p. 255-259.
- (2) 1902. On oxidizing enzymes in the vegetable body. *In* Bul. Col. Agr., Tokyo Imp. Univ., v. 5, no. 2, p. 207-235.
- (3) 1903. On the chemical nature of the oxidases. *In* Bul. Col. Agr., Tokyo Imp. Univ., v. 5, no. 4, p. 481-489.
- (4) 1905. Further observations on oxidases. *In* Bul. Col. Agr., Tokyo Imp. Univ., v. 6, no. 4, p. 371-374.
- (5) BAILEY, IRVING W.
1910. Oxidizing enzymes and their relation to "sap stain" in lumber. *In* Bot. Gaz., v. 50, no. 2, p. 142-147.
- (6) BERKELEY, M. J.
1876. Notices of North American fungi. Nos. 927-932. *Sphaeria jun-cina* - *Sphaeria semiimera*. *In* Grevillea, v. 4, no. 32, p. 146.
- (7) BETTS, HAROLD S.
1917. The seasoning of wood. U. S. Dept. Agr. Bul. 552, 28 p., 8 pl., 18 fig.
- (8) CLARK, ERNEST DUNBAR.
1910. The plant oxidases. 113 p. Easton, Pa. Bibliography, p. 94-111. Diss.—Columbia Univ.
- (9) 1911. The nature and function of the plant oxidases. *In* Torreya, v. 11, no. 2, p. 23-31; no. 3, p. 55-61; no. 4, p. 84-92, 101-110. Supplementary bibliography of papers recently published, p. 109-110.
- (10) ELLIS, J. B., and EVERHART, B. M.
1892. The North American Pyrenomycetes. A contribution to mycologic botany, 11, 3, 793 p., 41 pl. Newfield, N. J.
- (11) FRANK, A. B.
1895. Die Krankheiten der Pflanzen . . . Aufl. 2, Bd. 1. Breslau.
- (12) FREEMAN, E. M.
1905. Minnesota Plant Diseases. xxiii, 432 p., illus. St. Paul. (Minn. Geol. and Nat. Hist. Survey, Rpt. Bot. Ser. V.)
- (13) FRIES, ELIAS.
1823. Systema mycologicum. . . v. 2. Lundae.
- (14) FÜCKEL, LEOPOLD.
1869-70. Symbolae Mycologicae. Beiträge zur Kenntniss der Rhein-ischen Pilze. 459 p., 6 pl. Wiesbaden. (Jahrb. Nassau. Ver. Naturk., Jahrg. 23/24.)
- (15) GUM LUMBER MANUFACTURERS' ASSOCIATION. Technical Research Com-mittee.
1914. Digest [of report]. *In* Lumber World Rev., v. 26, no. 10, p. 44.
- (16) HAAS, PAUL, and HILL, T. G.
1913. An introduction to the chemistry of plant products. 401 p. Lon-don.

- (17) HARTIG, ROBERT.
1878. Die Zersetzungerscheinungen des Holzes der Nadelholzbäume und der Eiche in forstlicher botanischer und chemischer Richtung . . . Berlin. 6, 151 p., 21 pl. (15 col.).
- (18) 1900. Lehrbuch der Pflanzenkrankheiten. Für Botaniker, Forstleute, Landwirthe und Gärtner . . . Aufl. 3. 9, 324 p., 280 fig., 1 col. pl. Berlin.
- (19) HEDGCOCK, GEORGE GRANT.
1906. Studies upon some chromogenic fungi which discolor wood. *In* Mo. Bot. Gard. 17th Ann. Rpt., p. 59-114, 3 fig., pl. 3-12.
- (20) 1911. Prevention of mold. *In* Barrel and box, v. 16, no. 4, p. 35.
- (21) HUBERT, E. E.
1921. Notes on sap-stain fungi. *In* Phytopathology, v. 11, no. 5.
- (22) HUMPHREY, C. J.
1917. Timber storage conditions in the Eastern and Southern States with reference to decay problems. U. S. Dept. Agr. Bul. 510, 43 p., 10 pl., 41 fig.
- (23) [1920.] The decay of ties in storage. 35 p., 8 p. in text (pl. 1-3 col.) Baltimore.
- (24) ——— and FLEMING, RUTH M.
1915. The toxicity to fungi of various oils and salts, particularly those used in wood preservation. 38 p., 4 pl. Bibliography, p. 37-38.
- (25) HUNT, GEORGE M.
1916. The preservative treatment of farm timbers. U. S. Dept. Agr., Farmers' Bul. 744, 32 p., 17 fig.
- (26) JANKA, GABRIEL.
1907. Die Einwirkung von Süss- und Salzwässern auf die gewerblichen Eigenschaften der Hauptholzarten. Teil I. Untersuchungen und ergebnisse in mechanisch-technischer Hinsicht. *In* Mitt. Forstl. Versuchsw. Österr., Heft 33, p. 1-96, 16 fig.
- (27) KASTLE, J. H.
1910. The oxidases and other oxygen-catalysts concerned in biological conditions. U. S. Hyg. Lab. Bul. 59, 164 p. References to the literature, p. 141-161.
- (28) LAFAR, FRANZ.
1903. Technical Mycology: the Utilization of Micro-Organisms in the Arts and Manufactures. A Practical Handbook on Fermentation . . . v. 2, pt. 1. London.
- (29) LINDAU, GUSTAV.
1897. Sphaeriales. *In* Engler, Adolf, and Prantl, Karl. Die Natürlichen Pflanzenfamilien . . . Teil 1, Abt. 1, p. 384-491, fig. 252-288. Leipzig.
- (30) MCBETH, I. G., and SCALES, F. M.
1913. The destruction of cellulose by bacteria and filamentous fungi. U. S. Dept. Agr., Bur. Plant Indus., Bul. 266, 52 p., 4 pl. Bibliography, p. 47-50.
- (31) MÜNCH, ERNST.
1907-08. Die Blaufäule des Nadelholzes. *In* Naturw. Ztschr. Land. u. Forstw., Jahrg. 5, Heft 11, p. 531-573, 1907. Jahrg. 6, Heft 1, p. 32-47; Heft 6, p. 297-323, 1908. 33 fig.

- (32) 1909. Untersuchungen über Immunität und Krankheitsempfänglichkeit der Holzpflanzen. *In* Naturw. Ztschr. Land. u. Forstw., Jahrg. 7, Heft 1, p. 54-75; Heft 2, p. 87-114; Heft 3, p. 129-160. 5 fig.
- (33) NÖRDLINGER, HERMANN VON.
1860. Die technischen Eigenschaften der Hölzer für Forst- und Bau-beamte Technologen und Gewerbtreibende. 16, 550 p., 102 fig. Stuttgart.
- (34) PRATT, MERRITT B.
1915. The deterioration of lumber. (A preliminary study). Cal. Agr. Exp. Sta. Bul. 252, p. 297-320, 8 fig. References, p. 320.
- (35) ROTH, FILIBERT.
1895. Timber: an elementary discussion of the characteristics and properties of wood. U. S. Dept. Agr., Div. Forestry Bul. 10, 88 p., 49 fig.
- (36) RUDELOFF, M.
1897-99. Untersuchungen über den Einfluss des Blauwerdens auf die Festigkeit von Kieferholz. *In* Mitt. K. Tech. Vers. Anst. Berlin. Theil I-Bd. 15, Heft 1, p. 1-146, fig. 1-55, pl. 1-14. Theil 2-Bd. 17, Heft 5, p. 209-239, fig. 1-9, pl. 1-9.
- (37) RUMBOLD, CAROLINE.
1911. Über die Einwirkung des Säure- und Alkaligehaltes des Nährbodens auf das Wachstum der holzzersetzenden und holzfärbenden Pilze; mit einer Erörterung über die systematischen Beziehungen zwischen Ceratostomella und Graphium. *In* Naturw. Ztschr. Land u. Forstw., Jahrg. 9, Heft 10, p. 429-466, illus.
- (38) 1911. Blue stain on lumber. *In* Science, n. s., v. 34, no. 864, p. 94-96.
- (39) SACCARDO, P. A.
1878. Fungi veneti novi vel critici vel mycologiae venetae addendi. Series 9. *In* Michelia, v. 1, no. 4, p. 361-434.
- (40) 1882-1913. Sylloge fungorum . . . v. 1, 1882; v. 2, 1883; v. 9, 1891; v. 11, 1895; v. 14, 1899; v. 17, 1905; v. 20, 1911; v. 22, 1913. Patavii.
- (41) SCHRENK, HERMANN VON.
1903. The "bluing" and the "red rot" of the western yellow pine, with special reference to the Black Hills forest reserve. U. S. Dept. Agr., Bur. Plant Indus. Bul. 36, 40 p., 14 pl. (1, 3, 5, and 9 col.)
- (42) 1907. Sap rot and other diseases of the red gum. U. S. Dept. Agr., Bur. Plant Indus. Bul. 114, 37 p., 8 pl.
- (43) 1910. Prevention of blue stain in lumber. *In* St. Louis Lumberman, v. 46, no. 1, p. 60-61, illus.
- (44) ——— and SPAULDING, PERLEY.
1909. Diseases of deciduous forest trees. U. S. Dept. Agr., Bur. Plant Indus. Bul. 149, 85 p., 11 fig., 10 pl. Bibliography, p. 69-73.
- (45) SHERFESSEE, W. F.
1909. Wood preservation in the United States. U. S. Dept. Agr., Forest Serv. Bul. 78, 31 p., 4 pl., 3 fig.

- (46) SMITH, A. LORRAIN.
1918. Hyphomycetes and the rotting of timber. *In* Trans. Brit. Mycol. Soc., v. 6, pt. 1, p. 54-55.
- (47) SNELL, WALTER H.
1921. The relation of moisture content of wood to its decay, with special reference to the spraying of log piles. *In* Paper Trade Jour., v. 72, no. 18, p. 44, 46.
- (48) SPAULDING, PERLEY.
1906. Studies of the lignin and cellulose of wood. *In* Mo. Bot. Gard., 17th Ann. Rpt., p. 41-58, 2 col. pl.
- (49) TEESDALE, C. H.
1916-17. Use of fluorides in wood preservation. *In* Wood-preserving, v. 3, no. 4, p. 80-81; 1916, v. 4, no. 1, p. 6-10, 1917. Bibliography, p. 10.
- (50) TEESDALE, L. V.
1920. Manual of design and installation of forest service water spray dry kiln. U. S. Dept. Agr. Bul. 894, 47 p., 13 fig. (in text and on 1 pl.).
- (51) TIEMANN, HARRY D.
[1917.] The kiln drying of lumber. A practical and theoretical treatise. Ed. 3; 11, 316 p., 54 fig. and 8 diagr. (in text and on pl.). Philadelphia and London.
- (52) 1917. The theory of drying and its application to the new humidity-regulated and recirculating dry kiln. U. S. Dept. Agr. Bul. 509, 28 p., 3 fig.
- (53) U. S. DEPARTMENT OF AGRICULTURE. Forest Service.
1920. Timber depletion and the answer. A summary of the report on timber depletion and related subjects prepared in response to Senate Resolution 311. U. S. Dept. Agr., Forest Serv. Circ. 112, 16 p.
- (54) 1920. Timber Depletion, Lumber Prices, Lumber Exports, and Concentration of Timber Ownership. Report on Senate Resolution 311. 71 p., 22 fig. Washington, D. C.
- (55) WARD, H. MARSHALL.
1898. *Penicillium* as a wood-destroying fungus. *In* Ann. Bot., v. 12, no. 48, p. 565-566.
- (56) WEISS, HOWARD F.
1915. The preservation of structural timber. 18, 312 p., 32 fig., 47 pl. New York and London.
- (57) ——— and BARNUM, CHARLES T.
1911. The prevention of sap stain in lumber. U. S. Dept. Agr., Forest Serv. Circ. 192, 19 p., 4 fig.
- (58) WINTER, GEORG.
1887. Die Pilze Deutschlands, Oesterreichs und der Schweiz. . . . Abt. 2. *In* Rabenhorst, Ludwig. Kryptogamen-Flora. . . . Aufl. 2. Bd. 1. Leipzig.
- (59) YOSHIDA, HIKOROKURO.
1883. Chemistry of lacquer (Urushi). Part I. *In* Jour. Chem. Soc. [London], v. 43, p. 472-486.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
15 CENTS PER COPY



UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1038

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.

March 20, 1922

PECAN ROSETTE: ITS HISTOLOGY, CYTOLOGY, AND RELATION TO OTHER CHLOROTIC DIS- EASES.¹

By FREDERICK V. RAND, *Pathologist, Laboratory of Plant Pathology.*

CONTENTS.

	Page.		Page.
Types of chlorotic plant diseases.....	1	Studies of pecan rosette—Continued.	
Chloroses due to soil or atmospheric conditions.....	2	Histological and cytological studies.....	19
Infectious chloroses.....	6	Subsidiary experiments.....	30
Studies of pecan rosette.....	13	Probable nature of pecan rosette.....	31
Results of previous work.....	13	Summary.....	36
External signs of rosette.....	17	Literature cited.....	37

TYPES OF CHLOROTIC PLANT DISEASES.

The chlorotic group of plant diseases to which pecan rosette belongs has long been recognized and has presented to the investigator some of the most baffling problems in plant pathology. The potato-mosaic group began to assume alarming proportions in the British Isles and on the Continent toward the end of the eighteenth century and at the beginning of the nineteenth century (27, 45, 59).² Peach yellows was known and much written about in the United States near the beginning of the nineteenth century (69). Tobacco mosaic was first described by Mayer in 1886 (52), but more fully treated by Beijerinck in 1898 (17). Other well-known chloroses will readily come to mind in addition to those recently discovered or not so generally recognized.

It is not the purpose of this paper to consider in detail all types of plant variegation. Chloroses have to do with the reduction or

¹ The present study was largely carried out under the direction of Dr. R. A. Harper, of Columbia University, and was completed under the direction of Dr. Erwin F. Smith, of the Laboratory of Plant Pathology, Bureau of Plant Industry.

² The serial numbers in parentheses refer to "Literature cited" at the end of this bulletin.

total suppression of chlorophyll, but since a yellowing or bleaching of normally green parts may result from a wide variety of causes chlorosis in itself is a symptom rather than a disease. There are, for example, the chloroses of etiolation and of the normal autumnal ripening of leaves. Moreover, a yellowing of chlorophyll frequently follows upon some types of insect injury, such as that of root aphids on the peach and the grape, and it is a constant accompaniment of certain diseases caused by parasitic bacteria and fungi, such as bacterial black-rot of cabbage and *Fusarium* wilts of cabbage and potato. Again there are the more or less general chloroses due to unfavorable soil or climatic conditions, and finally those infectious chloroses of obscure origin which present a fairly regular sequence of pathological signs, including fundamental derangements in both metabolism and morphogenesis.

Some of these chloroses are true diseases in the restricted sense. Others are not diseases except under a broad application of the term, and certain forms of chlorophyll restriction are clearly not diseases at all.

There are, however, two fairly well marked types of chlorophyll disturbance which are usually included under the chlorotic group of plant diseases. These are (1) the infectious chloroses which are communicable through expressed plant juices or through those juices as directly transmitted within the living plant tissues, and (2) the noninfectious chloroses due to unfavorable soil or atmospheric conditions.

The present study of pecan rosette deals with the histology and cytology together with the sequence of gross symptoms of the disease. In order to place the results of this study in proper relation to other diseases of this type it is necessary to review briefly some of the work of other investigators.

CHLOROSSES DUE TO SOIL OR ATMOSPHERIC CONDITIONS.

With respect to those chlorophyll changes due to physical or chemical conditions of soil or atmosphere it is difficult to say just at what point the normal state ends and chlorosis begins.

Certain plants prefer an acid condition of the soil, others tolerate it, others are restricted for their optimum development to neutral or alkaline situations. Nevertheless, neither macroscopic nor microscopic examination of such a plant as field sorrel (*Rumex acetosella* Linn.), for example, would give a clue to its acid-soil toleration. In response to certain environmental changes, however, Transeau (78) has shown that this species does develop anatomical changes. In moist situations, with soil and air temperature approximately identical, the leaves of this species are relatively large, with a loose

arrangement of the tissues, a poorly developed palisade tissue of one-cell layer, three layers of sponge cells, and an epidermis of large thin-walled cells with delicate cuticle. On the other hand, when grown in dry sand or in undrained sphagnum bogs where the soil temperature was several degrees below that of the air the leaves were thickened, reduced in size, and revolute margined. The mesophyll tissue was more compact, with two or three layers of palisade, and two layers of sponge cells. The epidermal cells were smaller, with outer walls and cuticle thickened. In addition to the development of these other xerophilous characters, drops of oil or resin, characteristic of bog plants, were formed on the epidermis and cells adjacent to the bundles; these are absent under moisture conditions more favorable for this species.

Warming (82) states that in acid soils intimately associated with high water content, in a cold or temperate climate, the tendency of plants is toward the development of leaf coatings of hairs, papillæ, or wax; thickened cuticle; mucilage; erect and ericoid, terete, or filiform leaves; with bilateral internal structure. Since these characters develop on wet, moor soils the world over, he considers that there must be a connection between these soils and the xeromorphic structure, and that consequently these soils must be "physiologically dry." These facts also account for the xeromorphic structure of plants in the extreme north or at high altitudes.

The experimental results obtained by Mrs. Clements (23) show that the xerophyte tendency is toward the development of a diplophyll palisade (bilateral) tissue with restricted air spaces and with or without water-storage cells. This prolate closely packed type of cell tends to reduce transpiration. The mesophyte type, on the other hand, approximates an equal development of palisade and sponge cells with moderate looseness of structure. The hydrophyte type consists in the development of simple globose cells and large air spaces. She found that decreased light and increased water absorption caused an increase of leaf surface but a decrease in thickness, while increased light and decreased water absorption brought about a reduction in leaf surface but an increased thickness. Extremes of any factors not at the optimum tended toward dwarfing.

Hanson (39) found differences in total thickness between leaves from the south periphery and the center of the same tree usually greater than the differences hitherto reported between leaves of mesophytic and xerophytic forms of a species. Leaves from the south periphery, as a whole, developed more palisade, greater compactness of structure, and thicker epidermis and cuticle than leaves from within the crown.

Halophytes, or "salt-loving plants," usually develop thick, fleshy leaves which are more or less translucent, owing partly to the abun-

dant cell sap and poverty of chlorophyll and partly to the smaller intercellular spaces. The thickness of the leaves is caused by the enlarged roundish sponge cells and by the massive, often transversely divided palisade. Sodium chlorid thus appears to act morphologically, Warming says, in much the same way as sunlight (82). In the cell sap the solution of salt is more concentrated than in the soil. Side by side with this increased salt content goes a decrease in the development of chlorophyll, due to a reduction both in size and number of chloroplasts. Succulent halophytes usually show at first a dark-green color, later passing over into a yellowish green or red. Wax coatings are characteristic of many salt-loving plants. Some species, such as *Solanum dulcamara* Linn., are dimorphous, exhibiting halophytic forms and also inland forms with thin leaves.

Such general environmental factors as those enumerated may and do have appreciable developmental results. Plants thrive or fail to thrive and may even die, or again various general adaptive morphological changes are brought about, but there are no fundamental derangements in morphogenesis or in metabolism which could properly characterize these conditions as disease.

In this same category of general environmental effects are to be placed the calciphilous or lime-loving plants; and the calcifugous or lime-avoiding plants. Plants grown upon a lime soil, Warming says, tend to a greater pubescence and to a bluish green color and a more divided condition of the leaf (82). Moreover, not only are the chemical but also the physical characters of lime soils to be taken into consideration.

It is but a step, now, from these general lime relations to some of the more specific lime effects usually considered as diseases. In the pineapple chlorosis of Porto Rico sometimes the plant becomes almost ivory white. In other cases the leaves are yellowish white with streaks or patches of green, or the outer leaves may be green while the later developing leaves at the center are white from the start. In still other instances the leaves, normally green for several months, may gradually develop a light-colored mottling until finally the whole leaf becomes blanched. The plants are dwarfed and the reddish or pinkish fruit finally cracks open and decays. Gile (35-37) has definitely shown that this pineapple trouble is primarily caused by a lowering of the availability of iron to plant absorption due to calcium carbonate in the soil. A chlorosis of pineapple in Hawaii (46) appears to be caused by a similar depression of the availability of iron due to the high manganese content of the soil.

Similar lime chloroses of rice and of sugar cane in Porto Rico have been shown by Gile and Carrero (38) to be caused by a lack of sufficient iron absorption. In all these cases spraying with a solution of

iron sulphate evokes a development of chlorophyll and at least a temporary resumption of growth.

Grape chlorosis may also result from this same set of causes and in such cases responds to the ferrous-sulphate spray treatment. According to Mazé (53), grape chlorosis may also result directly from excessive absorption of lime, and in other cases from a deficiency of sulphur in the soil due to lowering of its availability by the action of lime. Furthermore, as a result of water-culture experiments he found chloroses of maize due to lack of both iron and sulphur. Chlorosis in maize was also experimentally induced by the addition to the solutions of various toxic substances, such as lead or methyl alcohol.

The overabsorption of lime was reported by Clausen (22) as causing a chlorosis of oats in Europe.

These plant relations to various salt constituents of the soil bring up the questions of plant absorption, antagonism, and changes in permeability investigated more recently by Loeb, Osterhout, Brooks, Waynick, and others. As the result of a careful series of experiments Waynick (83) concluded that no "optimum calcium-magnesium ratio" appears to exist and that a balance between all ions present in a solution appears to be far more important than any single ratio. He found by chemical analysis that the composition of plants in inorganic constituents may be enormously altered by variations in the surrounding medium. The permeability of the plasma membrane appeared to be changed by the nature and balance of the solution around the roots. The same salt was found to act differently at different concentrations, preserving the normal permeability at certain concentrations but at other strengths allowing a large penetration. With regard to each salt tested, its presence in toxic concentration always resulted in increased permeability of the plant tissues to calcium and magnesium. On the other hand, normal growth was always accompanied by an approximately equal percentage of calcium and magnesium in the plants tested; and in nearly all cases where growth was markedly decreased the amounts of calcium and magnesium were greatly increased in the tissues. The degree of absorption of any salt seemed, over a wide range, to be independent of the concentration present; and growth was the same under widely varying ratios of calcium and magnesium. The findings of Loeb, Osterhout, and Brooks were confirmed in that antagonistic salt action tends toward the preservation of normal permeability.

It will readily be seen that there are many closely intergrading steps or degrees of environmental effects. These are—

(1) The adaptations without visible changes in structure or metabolism.

(2) The general adaptive changes in anatomy or physiological processes in response to physical or chemical stimuli from without.

- (a) The dwarfing effects of unfavorable soil or climatic conditions.
- (b) Starvation phenomena due to insufficiency or absence of essential nutrients.
- (c) Chloroses caused by the absorption of toxic amounts of mineral or organic soil constituents.
- (d) The general chloroses due to insufficient or to overabundant water supply.
- (e) Restrictions in chlorophyll development due to reduction of light.
- (f) Finally there are chloroses due to lowering of temperature.

All these reactions, however, are rather general effects which are more or less comparable to starvation, overfeeding, or direct poisoning. There are no profound or strictly localized derangements in both metabolic and anatomical development, and it is a question whether in the restricted sense some of these phenomena should be regarded as diseases at all.

INFECTIOUS CHLOROSSES.

As opposed to the general chloroses caused directly by soil or climatic conditions are those specific chlorotic diseases of infectious nature and obscure origin in which are simultaneously brought about fundamental derangements in both physiological and structural development. Concomitant with the rise of plant pathology as a science there have come to light an increasing number of diseases of this type until now it seems apparent that almost every plant group may have one or more infectious chloroses.

Reports of early scientific investigations upon two of the principal types of infectious chlorosis appeared at nearly the same time—those upon tobacco mosaic by Mayer (52) and Beijerinck (17) and upon peach yellows by Penhallow (58) and Erwin F. Smith (69, 70).

In peach yellows the sign often first to appear is a red blotching of the fruit on one or more branches, with the color extending through the flesh to the pit. A yellowing of the foliage always occurs at some stage of the disease. Another characteristic feature consists in the premature development of the buds of several series into spindling depauperate shoots with dwarfed and linear and often curled or inrolled leaves. A premature ripening of the fruit also usually takes place. The disease ordinarily affects one or more branches at first, but may develop signs at once over the whole tree. Penhallow (58) found an abnormally loose cellular structure in the bark, but a reduction in the size of the cells and an abnormally dense structure of the wood. Assimilation is profoundly affected and translocation of starch is delayed. The leaves become gorged with starch, and excessive storage occurs in the cortex rather than in the inner bark and the wood, as in normal trees. The oxidizing enzymes are increased in the diseased leaves, and a larger tannin content has been found in the diseased fruit. In one instance (18) delayed starch translocation was also found in an apparently healthy branch con-

tiguous to a diseased branch, showing that external signs may be preceded by deep functional disturbances. Conditions unfavorable to growth tend to intensify the signs of yellows but do not cause the disease (71). Yellows is transmitted by budding or grafting from diseased trees to healthy stock, and infections through the roots as well as the stems may take place in this way. However, all attempts to infect with the expressed plant juices have thus far failed, nor have insect relations been discovered.

Peach rosette (70, 72) and little peach (73) differ in the character and sequence of the signs, but are similar in type to peach yellows. All three diseases induce deep changes in assimilation, translocation, structure, and development. All may appear first in one branch, and they are transmitted by budding or grafting. The disease progresses gradually from the point of infection, requiring longer for the development of external signs in the top when infected by root grafting than when grafted into the branches. That rosette may not affect the whole tree at once was shown in one case where buds from branches showing external signs transmitted the disease, whereas those from the apparently healthy side failed to give infection. The normal side of this tree, however, developed rosette the following season. The outer leaves of rosettes fall early.

In spike disease of the parasitic sandalwood we find a close resemblance to the peach-yellows group. The spikelike appearance of the leaves standing out stiffly from the branches suggested the name "spike disease." The entire tree is not attacked at once over the whole top, but symptoms appear first on one, then on several branches, and gradually spread over the tree. The internodes become shortened and the leaves reduced in size and narrowed. The continuous development of buds into new leaves and branches throughout the year produces a growth closely resembling the "witches'-brooms" of the peach, and with the progress of the disease the leaves become smaller and more chlorotic. No blossoms or fruit are borne in the later stages, though sometimes flowers and fully developed fruit are formed on portions of trees still retaining their normal appearance. Death of the haustoria and fine root ends keeps pace with the progress of the disease.

Spiked leaves and branches contain a marked accumulation of starch (24). In the diseased leaves this starch is distributed throughout the parenchyma, especially in the sheaths of the fibrovascular bundles, and no marked difference in quantity is found at different periods of the day. In the diseased twigs the starch occurs as grains of considerable size in the pith, in the medullary rays, in the wood, and in the bast fibers; whereas in the normal twig such grains are rarely found except when the leaves are fully matured. This accumulation in the twigs precedes external signs of the spike disease both

in natural and artificial infections. Diastase activity in the healthy leaves was found to be almost double that in the spiked leaves. The mesophyll tissues are hypertrophied and the leaves increased in thickness and the vascular tissues become reduced in advanced stages of the disease. Chemical analysis (24) shows a higher percentage of nitrogen and of most of the ash constituents in healthy leaves. Since young, healthy leaves pass through a stage comparable in chemical composition to that of spiked leaves, it seems probable that in the latter case development has for some reason been checked in the early stages of growth.

In a large percentage of Coleman's grafting experiments (24) spike was successfully transmitted to originally healthy stocks, and in almost every case the disease first appeared in the stock on branches closest to the point of grafting and spread from these regions to the other parts of the stock. A considerable time always elapsed before external signs of disease appeared. In all cases examined, infection had spread to the roots and resulted in the death of the root ends and haustoria.

The occurrence of spike disease is not dependent on the fertility of the soil, nor does injury to the roots have any relation to the disease. Venkatarama (81) found experimentally that isolation of the trees from all possible hosts by digging trenches did not cause signs of spike even after two years under observation. Cutting the root connections and removing the haustoria, injecting the lateral roots with strong sulphuric acid, and girdling to the heartwood did not cause the disease. Thousands of trees previously growing under a heavy covering of vines were exposed to the light, but the increased loss of water resulted in nothing resembling spike disease. Fischer (34) states that the spike disease spreads from a center, not appearing simultaneously over considerable areas.

In tobacco mosaic the yellow and green mottling of the leaves is a prominent sign. Not only leaves but also the calyx may be mottled, and the corolla becomes flecked with red and white blotches instead of exhibiting the normal even red or white color. The light areas of the leaves are usually slower growing than the green areas, thus often resulting in distortions which may become extremely marked in young leaves. Often, however, such leaves almost recover from these malformations as they mature (1). Sometimes the laminæ are almost suppressed, and in other cases a long, sinuous, ribbonlike leaf is produced. In many cases abnormally dark-green blisters develop on the immature leaves.

Koning (47) and Heintzel (40) reported a separation of the cells in diseased foliage which often leaves spaces nearly as large again as the cell itself. The chlorophyll bodies become distributed in irregular groups, chlorophyll disappears, the cell walls disintegrate, and finally

complete disorganization follows. Woods (84, 85) found that in the lighter areas of badly diseased leaves the palisade parenchyma had not developed at all, but the tissue consisted entirely of a respiratory parenchyma with cells packed together rather more closely than normal. In healthy leaves the palisade cells were four to six times as long as broad, whereas in the moderately diseased leaves these cells were almost as broad as long. The leaf surface becomes depressed in the light areas and raised in the green areas, thus giving a roughened appearance to the lamina.

As first shown by Woods (84), the oxidizing enzymes are greatly increased in the diseased areas. He also found more starch in the form of granules in the yellow areas than in the green areas of the same leaf. The cells were often completely gorged with starch. Examination in the early morning showed only a slight decrease, while healthy tissue at the same time was empty or contained only a trace. Starch translocation in the diseased leaf is greatly delayed in spite of the fact that diastase is present often in larger amount than in the normal leaf, and Hunger (41) from experiments *in vitro* concluded that the retarding effect upon diastase action is caused not by the oxidizing enzymes, but by reducing substances including tannin.

Mayer (52) first showed that transmission of tobacco mosaic could take place through the expressed juices of diseased plants. Iwanowsky (42), and Beijerinck (17) independently demonstrated that the infective principle would pass through the pores of a Chamberland filter, though such a filtrate was less infective than the unfiltered juice. Allard (4) proved that infection fails to result after the juice from diseased plants has been passed through a Livingston porous-clay cup filter. Transmission of the disease by an infective principle in the expressed juice was thoroughly demonstrated, and it was shown by Allard and others that oxidizing enzymes do not constitute this infective principle (4). Such plant juices diluted to 1 to 1,000 in water were quite as infective as the undiluted juice; attenuation was indicated at 1 to 10,000, while at greater dilutions infection was found unlikely to take place (2). The virus is infectious to all susceptible plants, but such plants never develop mosaic so long as chances for infection are excluded, and this regardless of soil and climatic conditions. The infective principle may be present in all parts of a diseased plant except within the seed and has been demonstrated even in the trichomes (3, 6). Furthermore, infection may occur through inoculation of the trichomes alone. Cutting the midrib at the base or severing the larger veins on one or both sides does not prevent the final dissemination of the infective principle to all parts of the leaf and to other leaves of the plant. Environmental conditions may partly or even wholly mask the external signs for a time, but can neither cause nor cure the disease.

Nishimura (55) found that the bladder cherry (*Physalis alkekengi* Linn.), after inoculation with tobacco-mosaic virus is capable of acting as a carrier without itself showing external signs of the disease. Cross-inoculation experiments (5) have shown that mosaics in tobacco, tomato, pepper, and petunia are caused by the same infective principle. On the other hand, the mosaic of pokeweed (*Phytolacca decandra* Linn.), though readily transmitted by expressed plant juices within the species, was not found to be cross inoculable on tobacco or vice versa (8). Tobacco mosaic is transmissible by insects.

Another type of infectious mosaic is that carefully worked out by Baur (11-16) in the Malvaceæ. He showed that the *Abutilon* mosaic is transmitted only by grafting and not by inoculation with the expressed juices, as occurs in tobacco mosaic. As in the latter disease, however, seed transmission does not occur. He found that when scions of the immune *Abutilon arboreum* Sweet are grafted on the variegated *A. thompsoni* Hort. they grow vigorously and remain apparently normal. However, if scions of the green but susceptible *A. indicum* Sweet are now grafted upon the immune *A. arboreum* they become infected and develop the typical mottling. On the other hand, the contagium passing through the immune *A. arboreum* is not capable of remaining there and giving infection if this portion of the shoot is subsequently grafted into a susceptible stock. In the case of the immune *Lavatera arborea* Linn., however, there is no transmission at all when double grafted between the mottled *Abutilon thompsoni* and the green susceptible *A. indicum*. Baur succeeded in transmitting this mosaic by grafting to about 50 species and varieties of *Abutilon* and related plants.

It was found that if the leaves of variegated plants were removed, or if the shoots were cut back so that no leaves remained and the new shoots developed in darkness, only the first two or three leaves were mottled. If these mottled leaves were then removed the plants remained permanently green in the light unless they were grafted with scions from other variegated plants. However, if axillary buds on old parts were forced into growth these produced shoots with mottled leaves which in turn infected all the newly formed leaves on the plant. Furthermore, when scions of a green but susceptible variety were grafted upon defoliated, mottled plants the scions remained green; but here again, if a mottled shoot was allowed to develop from the stock it rapidly infected the whole plant. The contagium is,³ therefore, capable of infecting only the embryonic leaves, and in the buds it may be stored up for months in inactive form.

³ The term "contagium" has been suggested by Dr. H. M. Quanjer as synonymous with any infective principle, whether of known or unknown origin. Its use in the place of "virus" with reference to the so-called "filterable-virus" diseases does away with objectionable connotations and leaves nothing to be taken back.

In varieties where the size and distribution of the yellow spots made it possible, Baur found that by carefully cutting out all yellow spots and continuing this process on all newly developing leaves for one or two weeks, finally green leaves only were formed. From this result he considered it certain that the contagium is present in the yellow spots but only in sufficient quantity to infect about three or four newly developing leaves at the growing point. After this it is apparently used up, and leaves subsequently formed remain green. Darkening the assimilating leaves of a mottled plant led to a similar result. Here the first leaves to develop thereafter were yellow spotted, but if these also were darkened before they began to assimilate, the subsequently developed leaves were all green.

Girdling experiments demonstrated that the contagium is carried only through the bark. Different species and varieties of *Malvaceæ* were found to vary widely in susceptibility and also in the incubation period, but several days at least are required. Baur also demonstrated infectious chloroses in *Fraxinus*, *Laburnum*, *Sorbus*, *Ptelea*, *Euonymus*, and *Ligustrum*.

In potato mosaic the mottling is irregularly distributed irrespective of the venation; and, moreover, profound dwarfing, with curling, crinkling, and further distortions of the foliage occur in the more severe attacks of the disease. The parenchyma tissues are less perfectly developed in the light-colored areas, the palisade cells tend to shorten up and chlorophyll development is restricted. Potato mosaic (65, 67) is transmitted by the tubers, by grafting, and by inoculation with the expressed juices of diseased plants; and it is also disseminated by aphids.

In potato leaf-roll the leaves become inrolled from the margin, reduced in size, and of a paler green to yellowish cast. A necrosis of the phloem (60-62) seems to be characteristic of the disease, but whether this condition is specific for leaf-roll is still a moot point. The disease is transmitted by means of the tubers, by grafting, and by insects (66).

In both potato mosaic and leaf-roll portions of the healthy plants growing near diseased plants contract the disease, but not all tubers from such secondarily infected plants necessarily develop diseased progeny. Affected leaves in both these diseases exhibit deep-seated assimilatory derangements, including increase in activity of the oxidizing enzymes and gorging of the leaves with starch, with greatly delayed starch translocation. In both these diseases tuber formation is greatly restricted. In neither case are these diseases induced or cured by soil or climatic conditions. However, certain environmental factors may temporarily mask the external signs though such diseased plants still retain their power to infect.

The infectious chlorosis of the sugar beet known as curly-top is not transmitted by expressed plant juices nor by way of the seed, but is disseminated by the sugar-beet leafhopper (*Eutettix tenella* Baker). This insect is capable of producing infection only after a definite incubation period subsequent to feeding upon diseased plants. Apparently there is no other agent of transmission for this disease (10, 68).

Some extremely interesting insect relations of spinach blight have recently been worked out by McClintock and Loren B. Smith (49). Not only were healthy plants successfully inoculated by needle pricks with the contagium from diseased plants and with the crushed juice of aphids fed upon diseased plants but the potato aphid (*Macrosiphum solanifolii* Ashmead) and the spinach aphid (*Rhopalosiphum persicae* Sulzer), free from infection at first, were demonstrated to transfer the blight to healthy spinach after feeding upon diseased plants. Control plants invariably remained healthy. Later, these two species were obtained from four different States where spinach blight did not occur, and they failed to induce the disease on healthy plants until after they had fed on blighted spinach. The same two species collected locally and tested at the same time produced the disease. These investigators demonstrated that the contagium may be carried from spring to fall by a direct line of aphids. Transmission tests with several other species of insects gave negative results, thus also tending to show that the insect relation to spinach blight is not that of a purely mechanical disseminator.

Sugar-cane mosaic has been shown by Brandes (19-21) to be transmitted by cuttings, by expressed juices from diseased plants, and by certain insects (*Aphis maidis* Fitch) fed upon infected plants. No evidence of seed transmission was found. Insect transmission of corn mosaic has also been demonstrated by Brandes.

That cucurbit mosaic is transmitted by the expressed plant juices and by insects has been definitely proved by Doolittle (28), by Jagger (43, 44), and by Doolittle and Gilbert (31); and the latter investigators have apparently shown that at least in some cases the disease is carried over by the seed (30). In this disease both foliage and fruit become yellow mottled and distorted, and growth of the entire plant is seriously checked. The dark-green portions of diseased leaves are slightly thicker than normal, thus accounting for their blistered and distorted appearance. The yellow areas, though thinner than contiguous dark-green parts, are of about the same diameter as in the normal leaf. The palisade cells of the green areas are crowded closely together and are somewhat longer and narrower than in the normal leaf. In the yellow parts these cells are more nearly isodiametric and less in number than normal per unit of area.

The spongy parenchyma of these parts is also more compact, and the intercellular spaces are smaller than in the green areas. The chloroplastids are decidedly smaller and often are pressed so closely against the cell wall as to be almost invisible. In the fruit the structural derangements are similar in general to those occurring in the diseased leaves.

Dilutions of the virus up to 1 to 1,000 were found to be just as potent as the undiluted juice expressed from diseased plants, but at dilutions greater than 1 to 10,000 no infections took place. Where infections took place with the higher dilutions, the incubation period was no longer than when undiluted juice was used, thus showing a rapid reproduction of the virus within the plants. This virus was found to be entirely removed by passage of the expressed juices through porcelain filters of the finer grades (29).

Taubenhaus (76) reported experiments in which mosaic of sweet peas was transmitted by insects and by needle inoculations with plant juices.

Reddick and Stewart (63, 64, 75) found mosaic of beans transmissible by rubbing the young leaves of normal seedlings with crushed leaves from mosaic plants and obtained a high percentage of mosaic by sowing seeds from diseased plants. In cases of inoculation external signs usually appeared after about four weeks.

Many other chlorotic diseases such as aster yellows, cassava leaf-curl, mulberry dwarf, cotton leaf-curl, little-leaf of the vine, citrus mottle-leaf, raspberry leaf-curl, apple rosette, and mosaics of peony and sweet potato present characters suggesting a possible relation to the group of infectious diseases. However, they have scarcely received sufficient study for any final statements regarding infectivity or causes. With this brief general review the particular disease under investigation may now be considered.

STUDIES OF PECAN ROSETTE.

RESULTS OF PREVIOUS WORK.

Pecan rosette was recognized by orchardists as far back as 1900, but no early published references to the disease have been found. Field investigations by W. A. Orton were undertaken in 1902 and continued about four years. During the years 1910 to 1913 field studies were carried out independently by the writer. The results of these two sets of field studies were brought together and published as a joint paper (56). With the exception of a few brief references to the disease, this was the first published account of pecan rosette.

The disease is fairly well distributed over the pecan-growing regions of the Southern States, but has not been reported from the northern limits of pecan culture.

TRANSMISSION.

In the investigation by Orton and Rand (56) negative results were obtained with inoculations using bits of diseased buds or tissue taken from beneath the bark of rosetted shoots, inserted into slits in the terminal branches of healthy nursery trees. Cultural methods and microscopical examination likewise gave negative results, showing the apparent absence of fungi or bacteria in still living rosetted twigs and branches.

Normal buds or scions worked on rosetted stocks all developed rosetted shoots except in one case where the stock itself recovered. On the other hand, rosetted buds and scions worked on apparently healthy stocks usually developed into normal shoots; in the cases where rosette did develop in such buds or grafts the percentage was no greater than in adjacent stocks worked with supposedly normal buds or grafts in the commercial propagation.

ENVIRONMENTAL RELATIONS.

The observations and orchard records by Orton and Rand (56) showed that pecan rosette is not absolutely limited to any soil type, topography, or season. The disease was found at least to some extent in practically all kinds of soils where pecans were observed, with the single exception of parts of some orchards where the land tended to be swampy. In the latter case very little growth was made, and the trees finally developed a diffuse general chlorosis, but no signs of any phase of rosette. The disease, however, was observed to be particularly prevalent under poor soil or cultural conditions for the species, such for example as in the dry uplands of Texas, or the washed-out hillsides of the Southern States. The disease was found to be comparatively rare in the alluvial river bottoms of Texas, Louisiana, and Mississippi, where the tree is under native environmental conditions.

In most cases where rosetted trees were transplanted into apparently better local soil conditions, the larger percentage of such trees and often all of them resumed normal development; and all rosetted nursery trees recovered when shipped from the South and transplanted in the open or in potted garden soil at Washington.

Nearly all healthy trees used to replace rosetted orchard trees subsequently developed the disease; whereas only about half of those replacing healthy trees later contracted the disease.

In a three-year fertilizer test on level uniform soil cases of rosette developed in 9 out of 11 plats where lime was used; and the largest number of cases and severest attacks occurred on two plats each receiving lime⁴ and acid phosphate, in one case combined with

⁴ Fertilizers were applied at the following rates: Lime (CaO acted on jointly by air and water), 1 bushel per tree; nitrate of soda, 8 pounds; cottonseed meal, 32 pounds; muriate and sulphate of potash, 8 pounds; acid phosphate, Thomas phosphate, and ground bone, 24 pounds; stable manure, a liberal application.

muriate of potash, in the other with nitrate of soda. The two limed plats free from rosette received in addition cottonseed meal and Thomas phosphate, respectively. In the five plats without lime no rosette at all developed with the exception of doubtful signs in two trees immediately contiguous to a limed plat. The four lime-free plats showing no traces of rosette were the control, untreated, and three plats treated respectively with muriate of potash and acid phosphate, stable manure alone, and stable manure with ground bone. During this period no other cases of rosette developed in the vicinity of the experimental block, though cases appeared in other parts of this orchard of 700 acres. In two other fertilizer tests where the disease was already present at the start, it increased somewhat in severity of attack or in the number of new cases in the plats receiving lime.

Analyses of the subsoil around normal pecan trees in parts of an orchard free from rosette gave 0.5 to 9.5 per cent of calcium. It appears then that the disease is not caused by the presence of lime alone, since more lime occurred here than in parts of the orchard where rosette was present. Ash analyses of normal and diseased leaves and twigs showed only slight or highly variable differences. Apparently, however, the percentage of potassium is greater in the diseased leaves and twigs.

In one spray test with Bordeaux mixture on rosetted trees negative results were obtained.

It is evident from numerous orchard records covering periods of 2 to 12 years that pecan rosette fluctuates from year to year without any variation in fertilization or cultural methods. The diseased trees may apparently make a complete recovery and remain normal for an indefinite period, or after one or more years may again contract the disease. However, in the majority of cases of recovery observed, the trees had not reached the stage where the branches were dying back. It seemed thus (56, p. 165, 169) highly probable that seasonal climatic changes, such as variations in precipitation or moisture content of the soil, might have at least an indirect relation to the prevalence of rosette. In large orchards the more or less simultaneous appearance of rosette in patches, and its usual limitation to these areas, suggested some connection with soil phenomena.

From the apparent nontransmissibility through the seed, negative results in attempts at isolation of organisms, the apparently negative results of budding and grafting between normal and diseased trees, and the results of transplanting tests it was concluded that the disease was probably nonparasitic.

From pruning and "dehorning" tests, transplanting and fertilizer experiments, dynamiting of soil around rosetted trees, and from orchard records of disease fluctuation it was at that time considered

highly probable that pecan rosette belonged to the group of non-transmissible chlorotic diseases caused by improper nutritive supply or injurious physical conditions. The possibility of the presence of some parasitic organism was not entirely precluded, but it was thought highly probable that the ultimate cause would be found in some lack of balance in nutritive supply, or possibly in some toxic substance or substances in the soil. These conclusions were based entirely upon the results of field experimentation.

Miller (54) observed that buds from rosetted trees worked upon healthy stock in most instances grew into normal trees, but that when a tree was decidedly rosetted its buds would sometimes develop the disease when worked upon healthy stock. He is of the opinion that rosette is due to soil relations and observed that in dry seasons the disease is more prevalent. Rosette and a proper amount of moisture, he says, do not go together. Impoverished soil, lack of humus, overstimulation of growth, and use of improper fertilizers all favor rosette. He states that the severest cases are incurable or at least not curable by practical means.

Fawcett (33) refers to pecan rosette in a short paragraph, and Crittenden (26, pp. 44-45) briefly summarizes the work of Orton and Rand.

Matz (51, pp. 139-141) in a bulletin relating to various pecan diseases and insects devotes a short section to rosette. He states that the disease apparently occurs on all types of soil and at all seasons, but that wherever it occurs it is most abundant during late summer. He also says that rosette is more abundant on higher and more exposed soils than in low and more protected situations. After briefly describing the signs of the disease he adds that many of the dead leaves adhere to the branches throughout the winter unless blown off by strong winds. The disease is favored by planting in open, sandy soil or where a hardpan exists near the surface.

McMurran (50) in a paper dealing with field experiments and observations states that rosette is generally considered to be the most serious pecan disease. It is found upon a wide range of soil types and under various conditions of culture and fertilization; but one factor, he says, appears to run through it all. On the river flood plains of Southern Louisiana the disease is practically unknown. Here the soil is deep and black and of high fertility and presumably of high water-holding capacity as compared with the typical sand, sand-clay, and clay soils of the Atlantic and Gulf Coastal Plains where the disease is so prevalent. In Georgia and Florida probably 90 per cent of the affected trees are on hilltops and slopes. All cases on the bottoms that have been examined were found to be in deep sand or in a clay or sand-clay soil underlain at 2 or 3 feet by sand. It was noted further that large healthy trees 5 to 10 years old



A. Hoen & Co. Baltimore

DIFFERENT STAGES OF PECAN ROSETTE.

[ILLUSTRATION BY J. F. BREWER.]

FIG. 1.—Enlargement of one of the yellow spots on a pecan leaf in the secondary stage of rosette showing the distortion of vein islets and their radial expansion around a focal center. X about 30. FIG. 2.—Pecan leaflet in the secondary stage of rosette, showing the distribution of yellow spots between the side veins and the crinkling and roughening of the leaf surface. Natural size. FIG. 3.—Pecan leaflet showing the red-brown stage of rosette which often follows either the primary or the secondary stage. Natural size. FIG. 4.—Pecan leaves in the primary stage of rosette, showing no external signs of the disease except the yellow mottling between the side veins. Natural size.



NORMAL PECAN LEAF, FROTTSCHER VARIETY.

Collected on August 25, 1919, at Thomasville, Ga. Photographed by transmitted light to show the texture and opacity of the leaf. $\times \frac{1}{2}$.



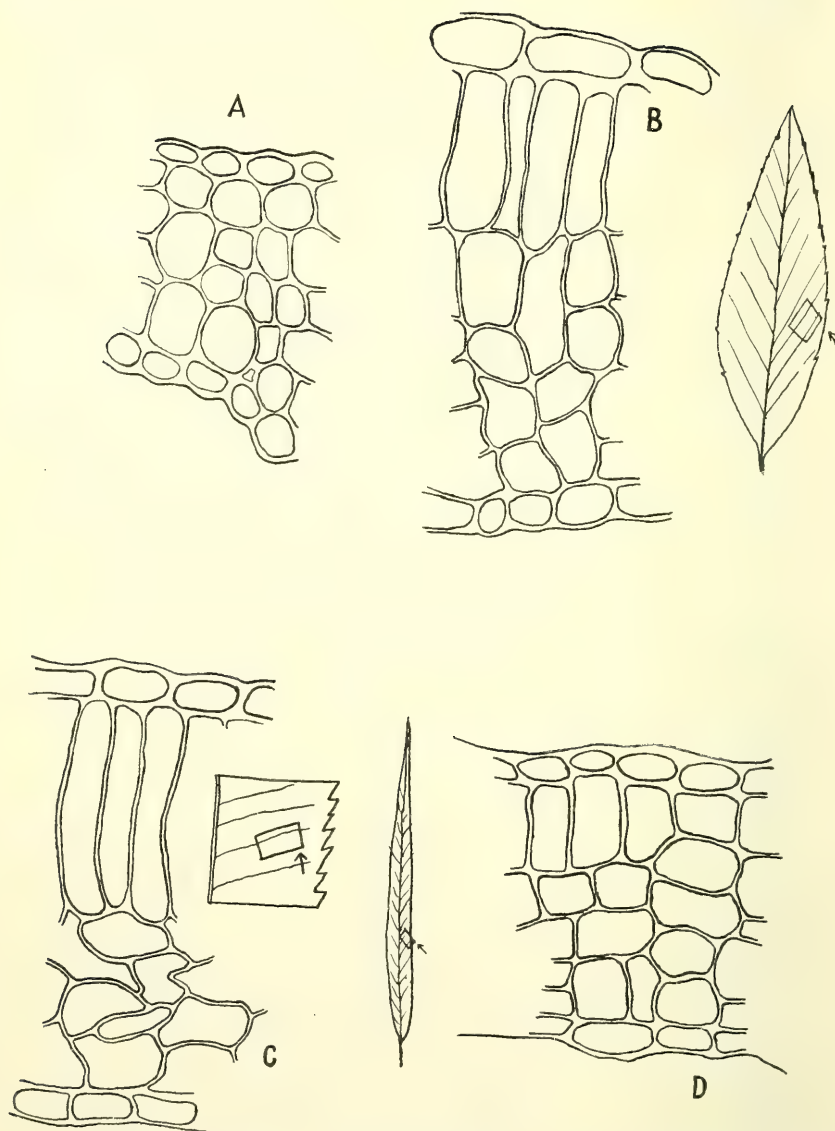
ROSETTED AND MOTTLED LEAVES OF PECAN, FROTSCHER VARIETY.

Collected on August 25, 1919, at Thomasville, Ga. Photographed by transmitted light to show reduction in size, yellow mottling, and abnormalities in form and texture of the leaves. $\times \frac{1}{2}$.



MOTTLED LINEAR LEAVES OF PECAN, FROTSCHER VARIETY.

Collected on August 25, 1919, at Thomasville, Ga. Photographed by transmitted light to show abnormal shape and texture. $\times 4$.



FREEHAND VERTICAL SECTIONS OF PECAN LEAVES, FROTSCHER VARIETY.

Semidiagrammatic camera-lucida drawings of diseased and healthy leaves, showing tissue changes due to rosette. Collected on August 25, 1919, at Thomasville, Ga. All of same magnification. The small side diagrams show the relative size and shape of the leaves and the locations of the sections. A.—Section through the center of a thin, yellow area, showing close packing of the cells and lack of differentiation. B.—Section at the margin of the yellow spot in the green portion of a leaflet, showing the close packing of the cells and the partial decrease in the long axis of a palisade cell and increase in the short axis of palisade cells. C.—Section through a healthy leaflet, showing palisade and spongy tissue well developed and the looser arrangement of the spongy cells, the narrower openings being intercellular spaces. D.—Section of a mottled, linear leaflet, showing the close packing of the cells and only partial differentiation of the palisade cells. Drawings by the writer.

often showed marked signs of rosette the first year after transplanting. Trees in low situations where humus and fertility accumulate from year to year were almost always found to be uniformly vigorous and free from disease. Briefly stated, 90 per cent of the cases of rosette were found under conditions indicating lack of humus, plant food materials, and moisture.

Fertilizer tests (50) showed in two years a marked improvement in rosette cases and also many cases of [apparent] recovery. Stable manure, particularly, gave excellent results. Rosetted trees in the plat that received ground limestone at the rate of 3 tons to the acre not only failed to improve but were more severely attacked at the end of the third season following its application than at the beginning.

Examination of large numbers of trees (50) showed that the feeding roots are distributed through the surface soil, and in proportion as this is deep and fertile do pecan trees usually attain their normal development and vigor. Long hot, dry periods often kill many of the feeding roots in the shallow surface soils; and deep sand, clays underlain by sand, and eroded hillsides were found particularly to favor rosette. An acid soil, according to McMurran, is probably not the cause, since river flood plains nearly all exhibit an acid soil, and pecan rosette under these conditions is a rarity.

EXTERNAL SIGNS OF ROSETTE.

Every phase of the disease is observed on trees of all ages, from young seedling or budded and grafted stock in the nursery row to trees of long-established maturity.

In every distinct case the constant sign of rosette consists in the final development of undersized, more or less crinkled and yellow-mottled leaves (Plate I, fig. 2; Pls. II to IV), particularly at the ends of one or more branches. This phase may be properly designated as the secondary stage of the disease. The chlorotic areas are situated between the principal veins, while portions adjoining these veins and along the margins of the leaflets are green. In severe cases these intervascular chlorotic areas are thinner than in healthy leaves, while along the midrib and principal veins the blade is often somewhat thicker than normal. This condition gives the leaf a peculiarly rough and furrowed appearance and causes the veins to stand out characteristically. Such leaves do not attain their normal size, are often linear (Pl. IV) and otherwise malformed, and present a crinkled or undulated appearance of the laminae. Parts of the laminae are often suppressed; sometimes the leaflet consisting merely of the midrib bordered by an edging of ragged tissue. In laminae otherwise fairly normal in general form, portions of the mesophyll

tissue occasionally fail to develop; as a result of subsequent growth stretching in contiguous tissues the blade becomes dotted with smooth-margined holes suggestive of healed insect punctures.

During the early course of the disease, or in cases of very slight attack, yellow mottling may be the only external sign (Pl. I, fig. 4), the size, shape, and texture of the leaves appearing normal. This primary stage is less characteristic than the secondary stage, but here also the chlorotic mottling is confined to areas between the principal side veins. The regions along the veins and leaf margins remain green. With advance of season the chlorotic areas of both primary and secondary stages often turn a dark reddish brown. (Pl. I, fig. 3.) Signs may appear over the whole tree at once, but frequently only one or more branches on a tree are affected at first. Early indications of rosette often consist in the appearance late in the season of a few mottled leaves near the tip of one or more branches, the remainder of the tree appearing normal. Leaves developing signs earlier in the season often present a general bronzed appearance during late summer and fall, and particularly is this true under conditions of drought.

Later, where the branches also become affected, there is considerable reduction in growth, so that the aborted leaves become clustered together on a shortened axis, giving the characteristic bunched appearance of the foliage at this stage (Pl. III, figs. A and C). It was this close bunching of the leaves that led Orton originally to apply the name "rosette" to the disease (56, p. 151). A few nuts are often borne on branches not too severely attacked, but they are usually malformed and reduced in size.

Affected trees may continue thus for several years, or they may appear to recover completely after showing moderate signs for one or more seasons. However, in severe cases where the signs have spread over the whole tree and in some instances where only one or more branches are severely attacked, the affected branches begin to die back from the tip during the latter half of the growing season. At first brownish spots and streaks develop in the chlorophyllous inner bark, and these dead areas increase in size until the bark and cambium are disorganized and the end of the twig or branch dies. This staghorn phase is followed during the current and subsequent seasons by development of abnormal numbers of shoots from dormant and adventitious buds. Usually in young rosetted trees the first shoots of the season are abnormally large and succulent, and the leaves are dark green and larger than normal. This is probably in part due to the severe pruning induced by the staghorn phase, since similar results are obtained by severe artificial pruning during earlier phases of the disease. Toward midseason, however, the mottling begins to appear and the later developed leaves present the

dwarfed, mottled, and roughened appearance typical of the secondary phase. Dormant and axial buds of one to several series may and usually do prematurely develop into depauperate shoots, and toward the end of the season clusters of dwarfed branches are usually put out from dormant and adventitious buds farther back on the branches or main trunk. With each repeated sequence of premature abnormal growth and subsequent dying back of the branches, the new twigs and leaves tend to become more and more depauperate, so that a well-marked case of several years standing presents a characteristically gnarled appearance.

HISTOLOGICAL AND CYTOLOGICAL STUDIES.

No less striking than the external changes brought about by rosette are the internal abnormalities of structure and metabolism in the leaf. The abnormal histological characters develop with the development of the leaf, and the most far-reaching internal derangements are found in cases of the greatest external malformation.

Within the yellow thin areas between the larger side veins (secondary stage) the tissue is usually less developed than normal, and the cells are more closely packed together (Pl. V, figs. A and B; Pl. VI, figs. E and F). In less severe cases the palisade tissue is well developed, but the intercellular spaces become almost obliterated (Pl. VI, figs. A, B, and D). In other instances the palisade cells are differentiated, but the individual cells are greatly shortened vertically (Pl. V, figs. B, C, and D) and may be only two or three times as long as broad, instead of seven to ten times, as in the normal leaf. In the most severely affected leaves with extreme variations in leaf diameter there is no differentiation into palisade and sponge tissue at all in the center of these yellow spots (Pl. VI, figs. E and F), but the tissue within these parts of the leaf consists entirely of closely packed, more or less isodiametric cells without conspicuous air spaces. Under these conditions the number of cell divisions may be somewhat increased, the cells remaining smaller than normal (Pl. VI, figs. E and F). Usually, however, the number of divisions is reduced, and in some instances a parenchyma tissue only three cells deep has been found. (Pl. V, fig. A.) Occasionally the entire tissue between the margin and the midrib consists of undifferentiated cells. That this lack of differentiation is not due to immaturity was shown by examination of young healthy leaves just after their emergence from the bud. Even at this young and only partially expanded stage the palisade tissue of healthy leaves was found to be well differentiated (Pl. VII, fig. C).

In the thickened portions along the veins, or sometimes throughout the laminae in the aborted nonmottled leaves of depauperate rosettes, the size of cells may become increased in all three dimensions without

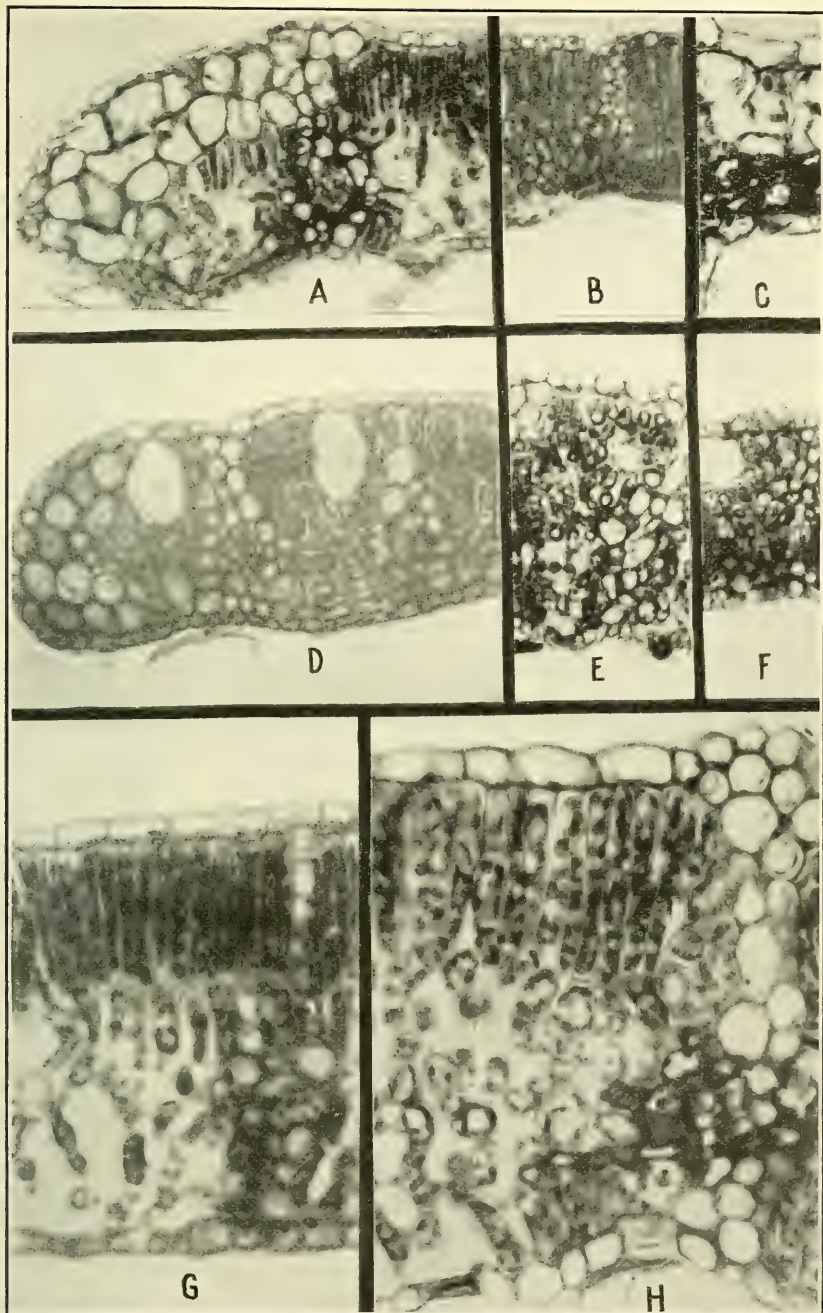
essential change in ratio between spongy and palisade tissue. (Pl. VI, figs. G and H; Pls. VIII and IX.) In some cases a slight increase in number of cell divisions also takes place (Pl. VI, fig. E). The individual cells appear abnormally healthy, and increase in leaf thickness here is due largely to increase in size of the individual cells (Table I). Along with this increase in cell size there is a reduction in size of intercellular spaces within the spongy parenchyma, and in the severely attacked leaf an almost complete obliteration of air spaces results (Pl. VI, figs. B to F).

TABLE I.—*Tissue and cell measurements of normal pecan leaves compared with those of leaves hypertrophied with rosette.*

Variety and leaf tissue.	Tissue and cell measurements (microns).			
	Normal.	Rosette, about half size.	Rosette, aborted.	Rosette, linear.
Frotscher variety, Thomasville, Ga.:				
Palisade cells...dimensions..	50 to 52 by 5.5 to 6.	57 to 60 by 6.5 to 9.5	58 to 67 by 8.5 to 10.	
Spongy tissue...thickness..	87 to 100.....	76 to 116.....	114 to 116.....	
Spongy tissue where palisade tissue is lacking:		33 to 65.....	61 to 70.....	
Upperepidermis.....	9.4 to 12.6.....	10 to 12.2.....	11.2 to 14.....	
Lower epidermis...do....	10.3 to 11.....	10 to 11.....	9.4 to 11.....	
Van Deman variety, Cairo, Ga.:				
Palisade tissue...thickness..	53.....	69.....		57
Spongy tissue.....do....	84.....	125.....		94

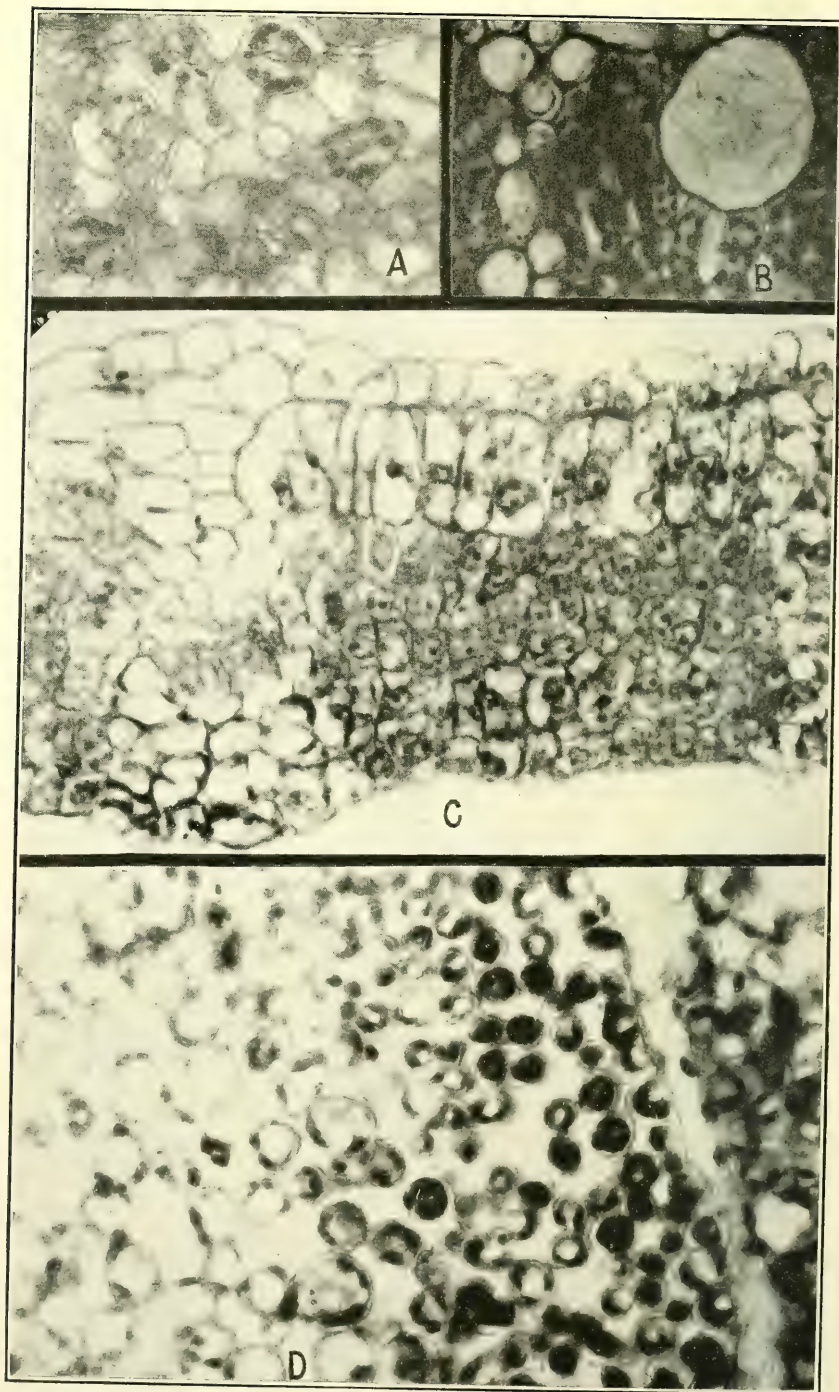
Linear leaves may or may not show a differentiation into palisade and spongy tissue, but where the palisade cells are developed they are usually shortened vertically and the spongy cells of the parenchyma are more closely packed together than the cells in healthy leaves (Pl. V, fig. D). The average thickness of these leaves tends to be less than normal and this reduction is due partly to decrease in the number of cell divisions and partly to the shortened vertical axis of the palisade cells. The elongated shape of the leaves, however, is not due to variations in cell shape but rather to a decrease in the number of cell divisions in which the central spindles are perpendicular to the midrib. This would tend to keep the cells closer to the main water supply of the leaf.

Amelung (9) working with plants and Conklin (25) working with animals have shown that normal tissue cells of corresponding organs or parts of organs within a species or variety are in general of the same size and that the size of organs is primarily due to differences in the number rather than in the size of cells. Mrs. Tenopyr (77), as a result of investigations in several species of plants, found that difference in the shape of leaves of the same plant or related species is not correlated with difference in the shape of their cells. Linear leaves are not composed of longer, narrower



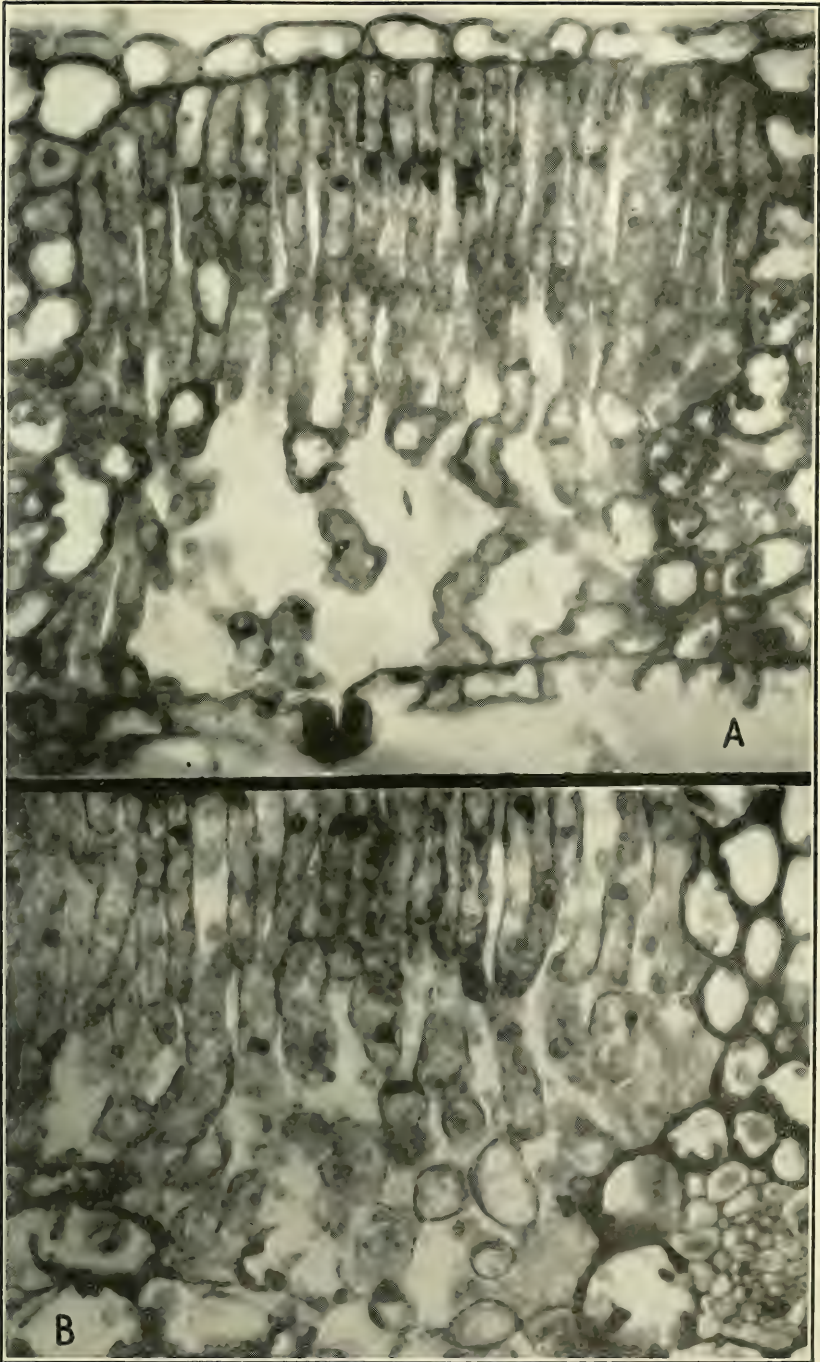
VERTICAL SECTIONS OF PECAN LEAVES KILLED WITH CARNOY'S FLUID.

Fleming's triple stain used. A, C, and E to H, Van Deman variety. Collected in July, 1913, at Belleview, Fla. A.—Section of healthy leaflet at the margin, showing well-defined palisade and spongy parenchyma and large intercellular spaces. B.—Section of a yellow, thin area in a large rosetted leaflet, showing a differentiated palisade, but close packing of the cells. C.—Section through the yellow area of a much-aborted leaflet where the tissues have partially collapsed. There is no well-defined palisade tissue. D.—Section of a badly mottled but nearly full-sized leaflet, showing the close packing of the cells. E and F.—Sections through the yellow, thin portions of a badly mottled but nearly full-sized leaflet, showing the lack of differentiation into palisade and spongy parenchyma, almost complete obliteration of intercellular spaces, and difference in the leaf diameters in the center (F) and toward the margin (E) of a yellow spot. G.—Normal leaflet, showing palisade cells well differentiated and typical loose arrangement of the spongy parenchyma. H.—Section through the green tissue around a yellow spot of a mottled leaflet, showing slight hypertrophy of the palisade and spongy parenchyma cells and the reduction in size of the intercellular spaces in the spongy tissue. A to F, $\times 220$; G and H, $\times 420$. Photomicrographs by the writer.



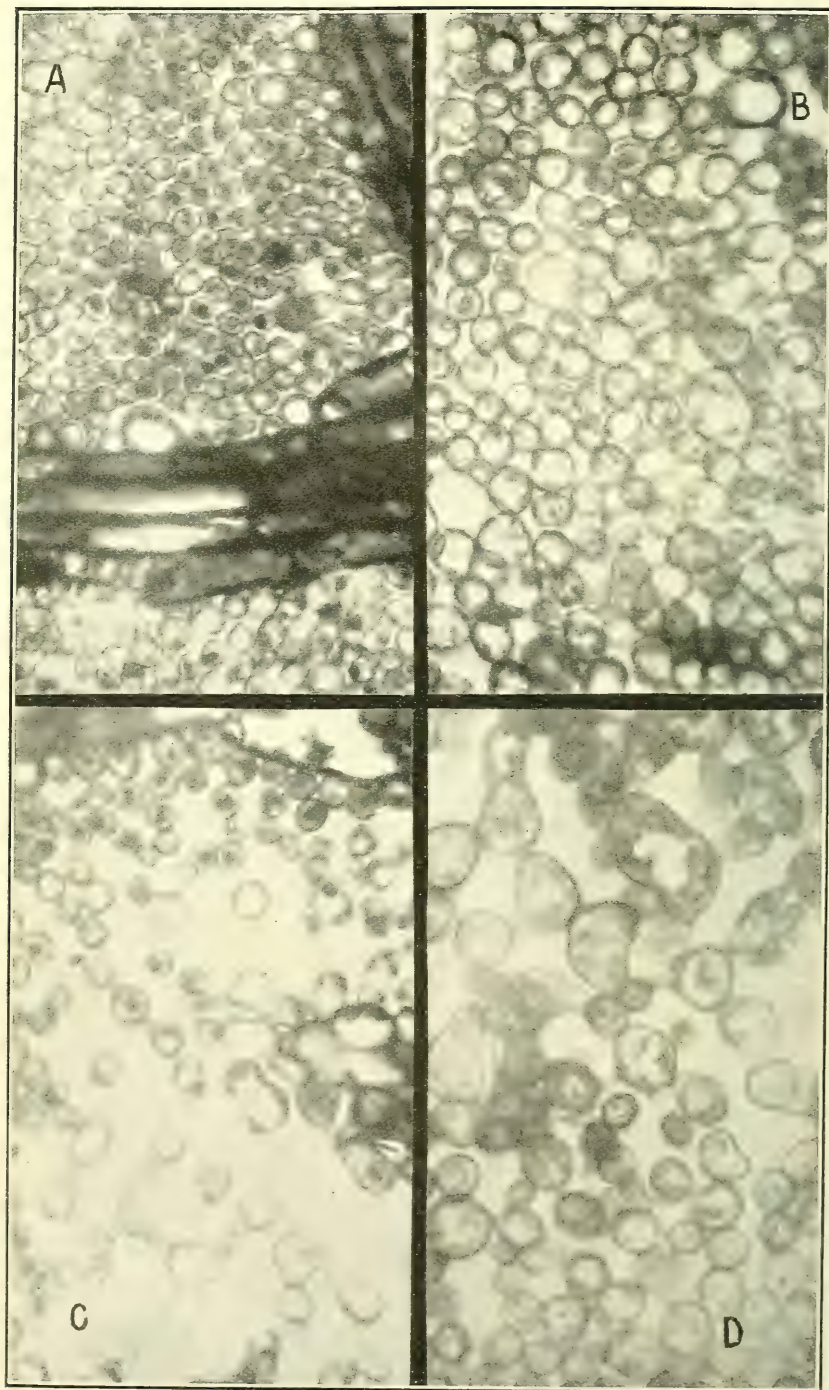
EPIDERMIS AND SECTIONS OF PECAN LEAVES.

A.—Epidermis of a healthy pecan leaflet collected before sunrise and stained with iodine to show the retention of starch in the guard cells. $\times 540$. B.—Vertical section of a pecan leaflet, showing a calcium oxalate crystal aggregate. $\times 420$. C.—Vertical section of a young pecan leaflet collected just after emergence from the bud, showing the differentiation of the palisade tissue at this early stage of development. Killed in Carnoy's fluid; Fleming's triple stain used. $\times 540$. D.—Horizontal section of spongy parenchyma at the margin of a yellow spot, secondary stage, stained with iodine to show the presence of starch in the green periphery but a smaller quantity or total absence of starch toward the center of the yellow area. $\times 540$. Photomicrographs by the writer.



VERTICAL SECTIONS OF NORMAL AND MOTTLED PECAN LEAFLETS, FROTSCHER VARIETY.

Collected in August, 1919, at Thomasville, Ga. Killed with Carnoy's fluid; Fleming's triple stain used. $\times 540$. A.—Section of normal leaflet. B.—Green portion of mottled leaflet, showing the enlargement of the cells, the reduction in size of the intercellular spaces in the spongy parenchyma, and the unevenness in the arrangement of the palisade cells. Photomicrographs by the writer.



HORIZONTAL SECTIONS OF NORMAL AND MOTTLED PECAN LEAFLETS.

A and B.—Horizontal sections through the palisade tissue illustrated in figures A and B of Plate VIII, showing the enlargement of the short diameter of the palisade cells in the mottled leaflet (B). C and D.—Horizontal sections through the spongy parenchyma illustrated in figures A and B of Plate VIII, showing the enlargement of the cells and the reduction in size of intercellular spaces in the green area surrounding a yellow spot in the mottled leaflet (D). All figures $\times 540$. Photomicrographs by the writer.

cells than rounded leaves of the same plant, but the narrower form of such leaves is due to a larger number of cell divisions with spindles parallel to the long axis.

In pecan rosette the general shape of the leaf seems to follow this rule, depending upon the orientation of the cell divisions rather than upon differences in the size or the shape of the cells. That is, the linear shape is not due to the development of cells elongated parallel to the midrib, but to a difference in the number of cell divisions in the two axes; nor are reduction in both length and breadth of leaf caused by a decrease in the size of the cells, but rather to a decrease in the number of cell divisions in both axes. On the other hand, there is often a large and localized change in both the size and the shape of the diseased cells, but not as related to leaf shape nor necessarily to leaf diameter. In the linear type of leaf the cells are as likely to be enlarged parallel to the short as to the long axis of the blade, and in portions of leaves profoundly reduced in both length and breadth the palisade and the spongy cells are at the same time often considerably enlarged in all three dimensions.

As a result of a considerable number of measurements of the thickness of leaves from healthy and rosetted trees of like age and variety, striking differences were found associated with the disease. (Table II.) Comparisons were made between leaves collected from the north and from the south sides of trees, but no constant differences were found which could be referred to situation, since all leaves were taken from the lower, outstanding branches, and under these conditions those on the north received nearly or quite as much light as those on the south periphery.

In each case the figures are based on 10 to 15 measurements of the thickness of each of several sections from comparable parts of each of 10 or more leaves. From such measurements it was found that the average variation from the greatest thickness in normal, individual leaves was 18 per cent, with extremes varying between 10 and 22 per cent. In the various types of rosetted leaves the extreme differences in thickness varied between 11 and 62 per cent of the greatest thickness. The least variation was found in the nonmottled linear or aborted leaves, while the greatest differences occurred in mottled leaves. Extreme variations in thickness of normal leaves of the Frotcher variety were 131 to 187 microns, while in diseased leaves of the same variety the range was from 70 to 234 microns. The smallest measurements were taken at the thin places in the leaves where tissue differentiation was lacking. The Van Deman specimens examined had slightly thicker leaves, but the same relations in thickness were found to hold between the healthy and the rosetted leaves of this and several other varieties.

TABLE II.—*Variation in the thickness of normal and rosetted pecan leaves, using the thickest part of each leaf as the standard of comparison.*

Description of material.	Measurements of thickness.		
	Average.	Extremes.	Variation average.
NORMAL LEAVES.			
Frotscher variety, Thomasville, Ga.:	<i>Microns.</i>	<i>Microns.</i>	<i>Per cent.</i>
North side of tree.....	162	131-187	18
South side of tree.....	147	122-173	18
Van Deman variety, Cairo, Ga.....	168	154-187	18
ROSETTED LEAVES.			
Frotscher variety, Thomasville, Ga.:			
Mottled leaves, about half size—			
North side.....	158	108-206	38
South side.....	167	80-210	37
Much-aborted leaves, south side—			
Nonmottled.....	152	70-215	26
Mottled.....	158	72-229	42
Linear leaves, south side—			
Nonmottled.....	118	103-141	26
Mottled.....	113	70-173	50
Mottled leaves, about half size, northeast side.....	139	75-234	55
Variety not stated, Cairo, Ga.:			
Mottled, red-brown stage, about half size.....	151	94-187	50
Van Deman variety:			
Mottled, about full size.....	198	140-281	45
Mottled, linear.....	140	78-195	47

The average thickness of linear leaves was always less than that of healthy or of other types of rosetted leaves. That this difference is not normally related to leaf size was shown by measurements comparing the thickness of the large juvenile leaves of normal young seedlings with that of the first type leaves above and that of large tip leaflets with small basal leaflets on single juvenile leaves. (Table III.) In the case of large juvenile leaves as compared with type leaves above there was a 67 per cent variation in the area of the laminæ, but only a 7 per cent variation in thickness. In the vascular portion of the large side veins, however, a 72 per cent variation in the area of the cross section was correlated with this increase in leaf size. (Table IV.)

TABLE III.—*Leaf thickness and vein diameter as related to size in normal young pecan seedlings.*

Description of material.	Thickness (microns).			Leaf variation (per cent).	
	Leaf average.	Leaf extremes.	Large veins.	Thickness.	Area.
Large juvenile leaves.....	103	94 to 117	515	7	67
First type leaves above.....	96	89 to 103	388		
Large juvenile tip leaflets.....	112	98 to 126	538	10	94
Small juvenile basal leaflets on same leaves.....	101	98 to 112	243		

In the large and small leaflets of single leaves a 94 per cent variation in leaf area gave only 10 per cent variation in leaf thickness; but here again there was a 92 per cent variation in the area of the cross section of the vascular tissue, corresponding to the 94 per cent increase in the area of the leaf blade. (Table IV.) It will be readily seen that the differences in leaf thickness are at the lower range of variation found in normal leaves. In these juvenile leaves the variation in area of the total cross section of veins was high, but not quite as great as the difference in leaf area; the area of the vascular part, however, increased in direct proportion with the size of the leaf, as would be necessary to carry an adequate supply of water and nutrients to and from the larger leaf blade. In these leaves very little variation was to be found in the vertical diameter of either palisade or spongy tissue.

TABLE IV.—*Tissue measurements as related to size in normal young pecan seedlings.*

Description of material.	Thickness of tissue.		Diameter of large side veins.		Area of cross section, large side veins.		Variation in areas.		Area of cross section, relation of vascular part to total veins.
	Palisade.	Spongy.	Total.	Vascular part.	Total.	Vascular part.	Cross-section, vascular parts.	Leaf.	
	<i>Microns.</i>	<i>Microns.</i>	<i>Microns.</i>	<i>Microns.</i>	<i>Square microns.</i>	<i>Square microns.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Large juvenile leaves.....	39	41	515	351	207,460	96,211	72	67	46
First type leaf above on same plants.....	40	30	388	187	118,215	27,172			
Large juvenile tip leaflets....	35	43	538	351	227,285	96,211	92	94	42
Small juvenile basal leaflets on same leaves.....	35	39	243	103	45,987	8,171			

The total area of the cross section of comparable veins in healthy leaves and in aborted leaves of approximately half size (Pl. III, fig. D) was nearly the same for a given variety and set of external conditions. However, the area of the vascular portion of these veins was reduced from 43 per cent of the total area of the normal to about 33 per cent of the total area of the diseased veins. In the greatly aborted leaves (Pl. III, figs. A and C) the area of the total vein cross section was about half that in the normal leaves, while the cross section of the vascular portion of these veins was only 10 per cent of the total vein cross section as opposed to 43 per cent in the veins of normal leaves. (Table V.) While the area of total vein cross section, except in the most aborted leaves, tended to remain the same as in normal leaves, the development of vascular tissue within the vein became greatly reduced with the reduction in the

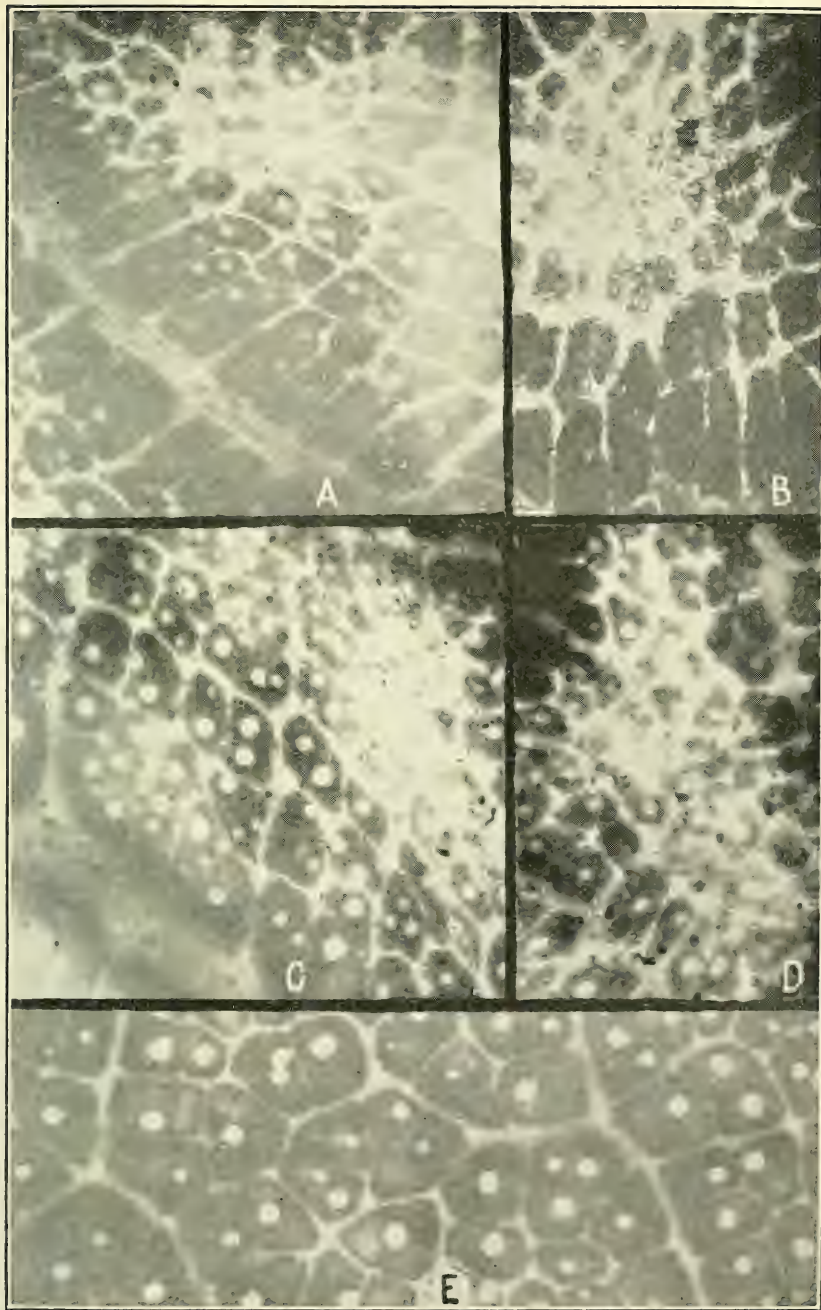
size of the leaf. In other words, the total size of vein in rosetted leaves of reduced size tends to be as great as that normally developed to support the full-sized leaf, but the development of vascular tissue within the vein becomes reduced with the severity of attack and consequent reduction in the size of the leaf blade.

TABLE V.—*Relation of vascular tissue in leaves to rosette.*

Description of material.	Diameter of large side veins.		Area of cross section, large side veins.		Area of cross section, relation of vascular part to total veins.
	Total.	Vascular part.	Total.	Vascular part.	
Frotscher variety, Thomasville, Ga.:	<i>Microns.</i>	<i>Microns.</i>	<i>Square microns.</i>	<i>Square microns.</i>	<i>Per cent.</i>
Normal leaf, south side.....	347	227	94,006	40,107	43
Rosetted leaf, about half-size—					
North side.....	359	202	100,641	32,041	32
South side.....	346	202	94,006	32,041	34
Aborted leaf, south side.....	259	83	52,269	5,280	10
Linear leaf, south side (midvein).....	487	180	85,472	25,442	30

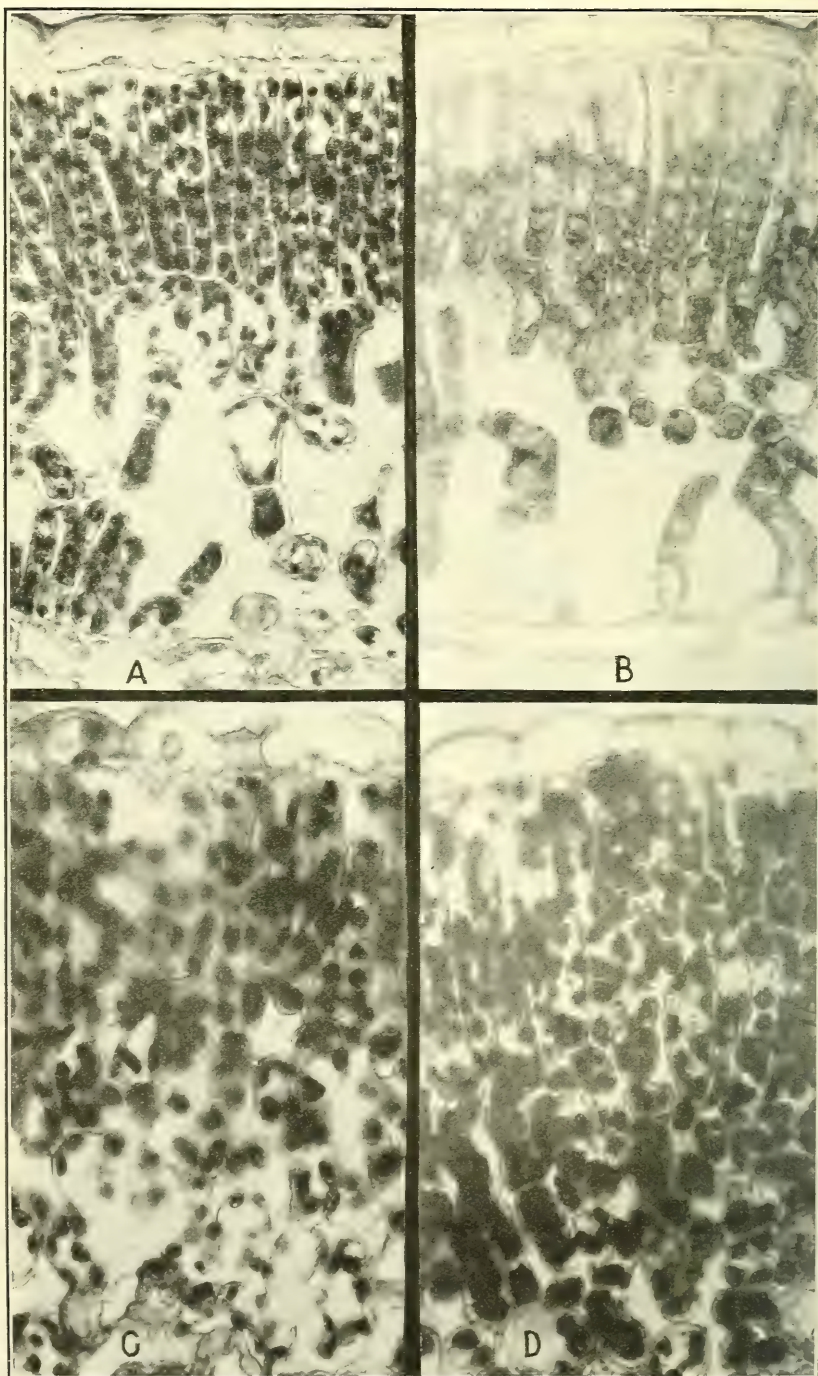
An examination of the vein islets of healthy and diseased leaves (secondary stage) has revealed striking differences in size, shape, and arrangement. Over the entire normal leaf blade these tiny areas bounded by the small, anastomosing veinlets tend to be isodiametric and of uniform size (Pl. X, fig. E). In the yellow areas, on the contrary, great differences in size and shape are the rule (Pl. X, figs. A to D). At the center of these spots the vein islets are smallest and become larger and larger with increasing distance from the center until often in the neighboring green parts they are considerably larger than in the healthy leaf. Their appearance suggests an inhibitory influence generated from the center, which largely prevents normal growth and differentiation there, but acts as a poison more and more feebly with receding distance from the focal center until in the neighboring green parts it has become sufficiently attenuated to function as a stimulant rather than as an inhibitory factor. This theory is also borne out by the writer's histological studies.

Not only are the vein islets highly variable in size, but they are often greatly distorted in shape. In many cases they are linear in outline, and with reference to the spot they approximate the arrangement of spokes in a wheel (Pl. I, fig. 1; Pl. X, fig. B). Thus it will be seen that the direction of their greatest expansion may or may not parallel the direction of greatest expansion in the leaf blade as a whole. That is, the size, shape, and arrangement of the vein islets in these chlorotic spots of the secondary stage are controlled from the focal center of the spot rather than by the normal morphogenic forces of the leaf.



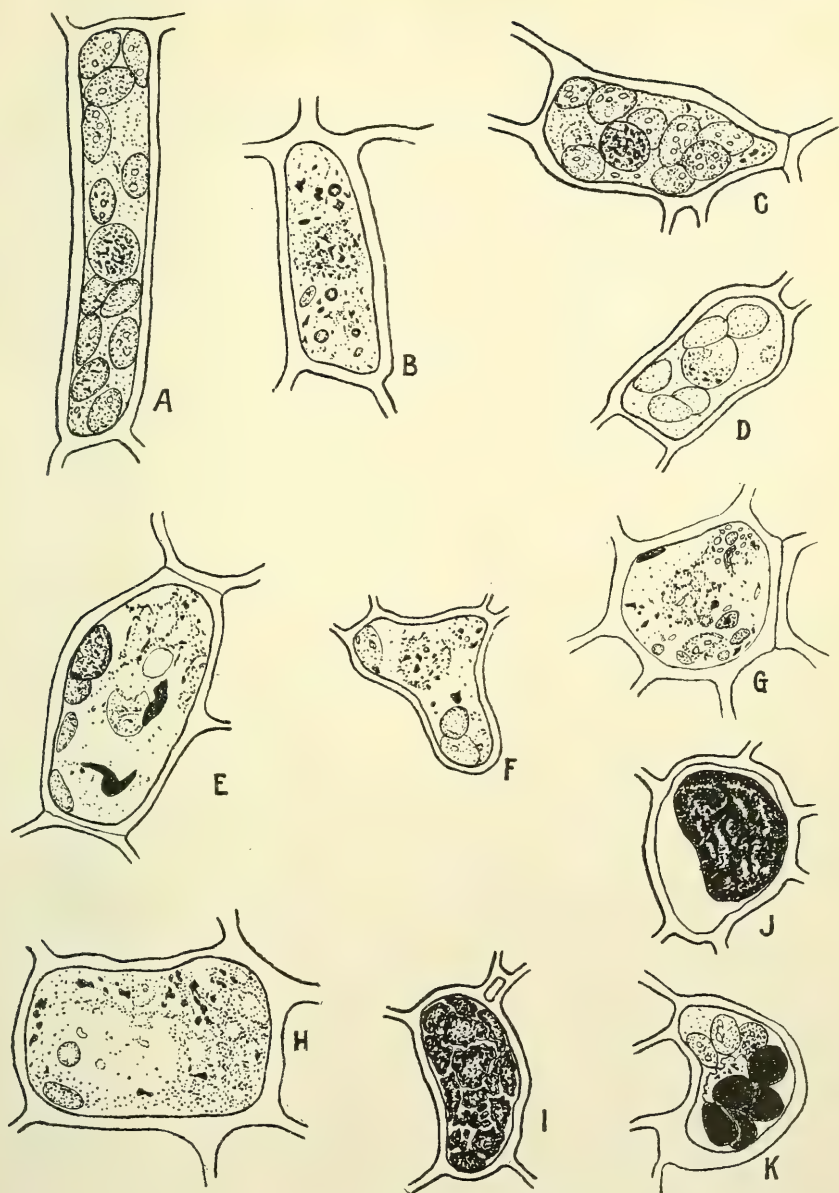
VEIN ISLETS OF UNSECTIONED AND UNSTAINED PECAN LEAVES.

A, and C to E are from photomicrographs of leaves preserved in alcohol. B is from a photomicrograph of a dry herbarium specimen. All at the same magnification. $\times$ about 60. The white spots are calcium-oxalate crystal aggregates. A to D.—Yellow spots of rosetted leaflets in the secondary stage, showing the distortion in shape and the variation in size of the vein islets. E.—Similar view of vein islets in a normal leaflet, showing approximately uniform size and regular arrangement. Photomicrographs by the writer.



VERTICAL SECTIONS OF HEALTHY AND DISEASED PECAN LEAFLETS,
FROTSCHER VARIETY.

Collected on August 25 and 26, 1919, at Thomasville, Ga. All figures at the same magnification. $\times 540$. A.—Healthy pecan leaflet collected at sundown, killed in Carnoy's fluid, and stained with iodine to show the presence of starch in the palisade and spongy cells. B.—Healthy pecan leaflet collected in the morning, killed in Carnoy's fluid, and stained with iodine to show the absence of starch. C and D.—Pecan leaflets aborted with rosette, collected and treated in the same way, respectively, as in the preceding two normal leaflets. Chloroplasts in both night (C) and morning (D) specimens were gorged with starch, and apparently no translocation had taken place during the night. Note also the enlargement of the cells in the diseased material. Photomicrographs by the writer.



FRESH LIVING CELLS OF PECAN LEAVES.

Camera-lucida drawings of freehand vertical sections, mounted in water. All at the same magnification ($\times$ about 1,200) and oriented the same as in the leaf. A.—Healthy palisade cell, showing well-defined nucleus and plump livid-green chloroplasts. B.—A disorganization stage of a palisade cell in a leaf affected with rosette; chloroplasts disintegrated and nuclear outline vague. C.—Healthy cell of the spongy parenchyma. D.—Slightly diseased cell of the spongy parenchyma in which the chloroplasts have lost a part of their green color. E.—Spongy parenchyma cell at the margin of a yellow area. The protoplasmic structures on the side toward the spot (right) are disorganized and the nucleus is fragmenting. Chloroplasts next to the green periphery of the spot (left) are still green and unfragmented, though a part of them are smaller than normal. F and G.—Spongy cells at further stages in disorganization. H.—Spongy cell showing entire disorganization of contents. I.—Tanin degeneration products gathering into floccules at a later stage of the disease in a spongy cell. J.—Spongy cell at the red-brown stage with more or less homogeneous reddish brown contents plasmolized. K.—Spongy cell at the margin of a yellow area (right) showing chloroplasts red-brown, but unfragmented on the side toward the spot. This form of injury is rather uncommon. Drawings by the writer.

A comparison of the size and shape of the vein islets in large and small mature leaflets on the pecan leaves and in large (mature) juvenile (undivided) and type leaves on the same normal seedlings showed very little variation. Ensign (32) found in healthy citrus leaves that the shape varied in different parts of the leaf, but the size was independent of the shape or location on the leaf. The size and shape of the vein islets in citrus were approximately the same in normal leaves and in chlorotic leaves of plants dwarfed from starvation. A comparison of the vein islets in large and small leaves on the same plant showed that the size was constant irrespective of the size of the leaf. A comparison of the leaves of all ages on the same plant showed that the youngest leaf had the smallest vein islets and with increasing maturity a corresponding increase in the size of the islets took place. Ensign concluded that the main skeleton of the vascular system is laid down very early in the history of the leaf and that but little differentiation later takes place. It is clear that in pecan rosette the size, shape, and arrangement of the vein islets are considerably altered from the normal. In fact, there is in the mottling of the leaves in pecan rosette much that appears comparable in origin to Liesegang's diffusion patterns, for example, those obtained with drops of silver-nitrate solution on a layer of solidified gelatin in which potassium bichromate had been dissolved. These "Liesegang phenomena" have also been compared by Küster (48) to the formation of growth rings by *Armillaria*, *Penicillium*, and other fungi, to the alternative lighter and darker areas of some leaf-spot diseases of fungous or bacterial origin, and to a great variety of pattern phenomena in both plant and animal kingdoms. The end results in all these cases of organic origin are similar in appearance to those obtained by diffusion experiments carried out in vitro. Furthermore, while great caution should be exercised in the interpretation of such experiments the results are extremely suggestive that diffusion in colloidal systems plays a prominent rôle in the development of the pattern phenomena in both health and disease.

Profound derangements take place in starch assimilation and translocation. In healthy leaves collected at sundown the starch content of the chloroplasts is uniform for each tissue with usually the greatest accumulation in the palisade cells (Pl. XI, fig. A). Stained with iodine the starch is seen in a more or less irregular mass at the center of the chloroplasts but in no case completely filling the plastid. Starch also occurs in the guard cells and in occasional plastids in the bundle sheaths. Healthy leaves collected before sunrise the following morning from similar situations on the same trees in general showed no starch at all (Pl. XI, fig. B). In these healthy leaves the iodine gave merely a yellow stain to the cell contents. An extremely rare

palisade or spongy cell and many of the guard cells were, however, filled with starch as in leaves collected at sundown (Pl. VII, fig. A).

Mottled leaves of all sizes collected at night showed the green portions gorged with starch (Pl. XI, fig. C). The plastids of the palisade and spongy cells were not only filled to the periphery but swollen as if almost bursting with their accumulation of starch. Toward the center of the yellow spots (secondary stage) the chlorophyll bodies are of less and less frequent occurrence until at the center only an occasional starch-filled plastid is to be found (Pl. VII, fig. D). In these areas where the effects of the disease have been in operation from the early stages of bud growth the inhibitory influence has affected not only tissue differentiation but has also prevented normal development of the plastids.

Mottled leaves collected before sunrise the following morning appeared the same as those collected at night (Pl. XI, fig. D). As far as could be determined from the iodine stain, no translocation at all had taken place during the night. Palisade cells, spongy cells, and guard cells of the green areas were full of starch, and the occasional plastids in the bundle sheaths of the veins were also gorged.

The nonmottled, but greatly aborted leaves, showed this gorging of the plastids over the whole lamina. The starch sheaths around the midveins were also black with starch. As in the other diseased leaves the plastids appeared as full of starch in the early morning as at the end of a sunny day.

Wherever plastids are present in either stage of leaf mottling the first sign of disease in these bodies consists in a gradual loss of the green chlorophyll. In the healthy living cell of both palisade and spongy parenchyma the plastids are plump and of a livid green color, while the nucleus is plainly visible as a grayish, more or less centrally located body with definite outline (Pl. XII, figs. A and C). As the disease progresses these chlorophyll bodies first lose their green color (Pl. XII, fig. D), then both nucleus and plastids begin to break down (Pl. XII, figs. B and E to H), first losing their definiteness of outline, or becoming fragmented or appearing as if eaten away at the periphery. Later all the visible remains of the cell structures consist of globules, probably fatty, and darker-colored granules of various shapes and sizes irregularly distributed throughout the cell, with all appearance of disorganization. With ferrous salts many of the brownish granules gave the reaction for tannin. In cases of severe attack the entire tissue within these yellow areas later becomes reddish brown and collapses (Pl. I, fig. 3). In reaching this end stage the tannin degeneration products here described gather into larger and larger floccules (Pl. XII, fig. I) until finally the cell may be filled with a more or less homogeneous reddish brown matrix,

which later recedes from the cell wall (Pl. XII, fig. J), and at last the whole cell collapses and shrivels.

The deposition of crystal aggregates of calcium oxalate is characteristic of pecan leaves (Pl. VII, fig. B). These crystals begin to form in giant binucleate cells of the palisade just after the young leaf emerges from the bud. Finally the protoplasmic contents disappear, and the crystal aggregate nearly fills the cell. These crystal aggregates are distributed with considerable regularity in the healthy leaf and in the majority of cases one to each vein islet (Pl. X, fig. E). In the yellow spots of the secondary stage of the disease, on the other hand, their formation and distribution vary widely. At the focal centers in severe cases few or no crystals at all are formed, whereas in the surrounding green parts they are often far more numerous and sometimes larger than in the comparable healthy leaf.

Averaging a large number of counts in cross sections of green parts of diseased and normal leaves of the Frotscher variety collected at Thomasville, Ga., it was found that in the normal leaves 20 crystal aggregates occurred to every 100 vein islets observed in section, while in the diseased leaves 60 crystal aggregates were found to every 100 vein islets. In Van Deman leaves collected at Baconton, Ga., there were 16 crystal aggregates to every 100 vein islets in the healthy leaves as compared with 54 in the diseased leaves. Furthermore, after all due allowance for differences in cortical area of the diseased and healthy leaves compared, a much larger number of these crystals was found in the cortex of petioles and midveins in rosetted leaves. In view of the fact that waste organic acids usually accompany carbohydrate formation (57, p. 173) these results are significant. Since growth at the periphery of the yellow spots in the secondary stage is often abnormally active, as is shown by the size of the cells, an unusually large accumulation of such organic acids would naturally be expected to take place in that region. Conversely, with the reduction of chlorophyll formation and assimilation in the centers of the spots a smaller production of such acids would occur.

Development of the shield-shaped resin glands occurring mostly on the lower surface of the leaves is also profoundly affected by the disease. On the normal leaf these glands are rather regularly and sparsely distributed over the surface of the blade and contiguous to the veins and veinlets. In diseased leaves of the secondary stage, on the contrary, the focal centers of the yellow spots are often thickly covered with these resin glands both contiguous to the veinlets and well within the vein islets themselves. The more severe the general effects of the disease the more numerous were these glands found to be, until in places where the tissues were practically de-

funct or bordering wounds where such tissues had fallen out, they presented a continuous, rough layer of glandular shields. Examination of ordinary leaf wounds such as those made by insects showed no such abnormal development of resin glands. These conditions have been frequently observed in the general examination of leaves collected during several seasons and in different varieties and localities. Furthermore, using a simple binocular microscope, observations have been checked up by exact counts. For example, counts were made of the numbers occurring in a single field in different parts of 10 normal leaves of the Frotscher variety collected at Thomasville, Ga. (1916), and in the yellow areas of 10 comparable rosetted leaves. The average for normal leaves was 8 to a field, while in the diseased leaves there were 92 to a field. In a lot of the Schley variety collected at Orangeburg, S. C. (1920), the average for healthy leaves was 43 and that for comparable yellow areas of diseased leaves 212 to a field. Similar results were found in material collected at Belleview, Fla., and at Baconton and Cairo, Ga. In some older spots of the secondary stage these resin glands were so closely packed together that counting was impossible.

This increased development of resin glands is characteristic of many halophytes and xerophytes and in these cases apparently bears some relation to the condition of physiological dryness. Furthermore, Tschirsch (80) has demonstrated that the secretion of resin is produced within the cell wall itself just below the cuticle. This region he calls the "resinogenous layer." Nutrient substances and water pass out of the protoplast into this resinogenous layer, to be there further molded into the final product, resin. This process, then, is participated in by both protoplast and cell wall and necessitates loss of material from both and a final breaking down of the cell wall itself. In pecan rosette this abnormal development of resin glands is then probably to be connected in some way with the gradual and general degeneration of the cells involved.

In order to determine whether new spots may be formed after the full expansion of the leaf and whether yellow spots already formed may increase in size, resort was made to careful field observation and microscopical study of fresh living material. On July 20, 1920, at Orangeburg, S. C., the outlines of several hundred spots on 56 different leaves of both primary and secondary stages were carefully traced with India ink on the upper surface of the blade. At the same time the outline of one leaflet on each leaf was traced on paper for comparison with its size at the end of the observational period. Furthermore, nonmottled areas of diseased leaves were marked in a similar way; and finally also certain areas of normal leaves were so marked as a check on possible injury by the India ink. These leaves were located on one normal and five rosetted trees in a 45-acre

pecan orchard of the Schley variety at Orangeburg, S. C. Final notes were taken on a portion of these leaves at the end of 10 days, while the remainder were left until September 9, 51 days later.

In leaves of the primary stage, after 10 days, 17 yellow spots had developed within 170 previously marked green areas. Of 130 yellow spots already present, 11 in all had increased in size but only 2 conspicuously so. In slightly affected leaves of the secondary stage, 36 green areas had developed 13 yellow spots; and out of 26 spots already present 19 had increased in size, 15 of them decidedly. In the considerably aborted leaves, 109 green areas had developed 137 new spots; and out of 270 spots present at the start 193 had increased in size, 70 of them by at least 50 per cent of their original diameter. These leaves were all fully expanded at the beginning, since no appreciable increase in size of blade could be discerned on comparing the leaflets with their original tracings. The check leaves remained normal and evidenced no ill effects from the presence of the India ink.

Four uniformly pale leaves recently out of the bud and not fully expanded at the first observation, at the end of 10 days, had developed a conspicuous green color around the margins and along the veins, but had failed to develop further chlorophyll in the centers of the areas between the lateral veins. These leaves were now typical of the secondary mottled stage.

In those leaves left for 51 days, 33 green areas in the primary stage leaves had developed only 2 yellow spots. Of 180 spots already present, 86 had increased in size, but only 15 decidedly so. In aborted leaves of the secondary stage, 50 green areas had developed 17 spots and of 66 spots present at the beginning 50 had increased in size, and 37 of them decidedly so.

Most of the leaves of the primary stage were at the beginning older and fully matured. The leaves of the secondary stage were fully expanded, but for the most part soft and immature. It is thus apparent that these yellow spots are not necessarily laid down in the bud stage of the leaf or in a definite and unchangeable pattern, as may be the case in certain heritable variegations. It is clear also that spots may develop *de novo* even after expansion of the leaf blade and that those already formed may increase in size, though less rapidly and frequently after the leaf has fully matured.

That yellow spots may increase in size was also shown by a study of free-hand sections of fresh, living material. Here on the margins of the spots an occasional cell was found which showed disorganization of its internal structure on the side bordering the yellow area, while that part of the cell contents toward the green periphery approximated the normal. (Pl. XII, figs. E and K). Here again appearances suggest the outward diffusion of some toxin from a focal center of its production.

These changes in mature cells affect the protoplasmic structures rather than the cell size, shape, or other so-called histological characters. They consist in such changes as loss of chlorophyll, breaking up of the nucleus, and degeneration of the cytoplasm. The situation seems to be that the toxic substances which in the embryonic stages may produce the profound alterations in morphogenetic processes of leaf formation described above, in the mature leaf cells are simply destructive of the still plastic protoplasm. What the ultimate expression of the disease will be depends, then, upon the ontogenetic stage of the plant organ at which the cause becomes effective.

SUBSIDIARY EXPERIMENTS.

In order again to test the effect of subjecting pecan trees to varying environmental conditions, further transplanting and fertilizer experiments were conducted on a small scale at the New York Botanical Garden.

In one of these experiments 32 large nursery trees showing severe attack of rosette during the summer of 1913 at Monticello, Fla., were transplanted late in the fall to large pots of garden soil in one of the botanical garden greenhouses. On account of the length of the tap roots these trees were so severely root pruned that only a part of them survived. However, the 18 remaining trees were under observation for two seasons, and at no time during this period did any sign of rosette develop although before transplanting all were badly mottled and dying back from the tip.

In another test several pecan nuts were germinated in fine quartz sand in each of 32 glazed crocks and in 4 similar crocks of garden soil. All were uniformly watered by the porous clay cup autoirrigation method. The crocks containing sand were divided into 8 lots receiving the following different fertilizer treatments:

- (1) Liberal application of a commercial fertilizer containing muriate of potash, ammonium sulphate, and acid phosphate.
- (2) Liberal application of a fertilizer made up of sulphate of potash, slaughter-house tankage, and Thomas slag.
- (3) An excess of stable manure.
- (4), (5), and (6) An excess, respectively, of slacked lime, magnesium sulphate, and ferrous sulphate.
- (7) Equal quantities of slaked lime and magnesium sulphate.
- (8) Control, untreated.

Lot 9 consisted of the 4 crocks with garden soil alone. All seedlings germinated normally and were under observation during one season. All those in lots 1, 2, 3, and 9 made good growth and appeared dark green and healthy throughout the experiment. Seedlings in the other lots started out well but after using up the nutrients in the seeds they became stunted and finally developed a general

yellowing of the foliage. However, none of the mottling or other signs of rosette appeared at any time during the season.

Two large, healthy seedling pecans were transplanted to a plat of garden soil containing a great excess of lime where mortar had previously been mixed for building purposes. These trees have been under observation for three seasons, and no signs of any type of chlorosis have at any time become evident.

In another small experiment run for two months, 10 seedlings potted in garden soil were given liberal and fairly uniform applications of water throughout the period, while 10 similar potted seedlings were given only sufficient water to prevent wilting. In the latter case but little growth was made, and a part of the leaves developed a general chlorosis. At no time, however, were any signs of rosette to be seen.

PROBABLE NATURE OF PECAN ROSETTE.

In the writer's opinion the pathogenic picture of pecan rosette as shown in the preceding pages, including histological and cytological features, is much more in agreement with the infectious type of chloroses, including the yellows and mosaic groups, than with those chloroses known to be caused directly by soil or climatic conditions. It is not considered, however, that adequate proof has yet been given on either side, and the present study is offered merely as one more step in the study of this baffling group of diseases and as a suggestion for further research.

In the environmental type of chlorosis structural changes may occur. The xerophytic tendency is toward a bilateral palisade with restricted air spaces reducing transpiration. Hydrophytic conditions produce large, globose cells and loose arrangement of tissues. Excess of sodium chlorid develops enlarged, rounded, spongy, and massive palisade cells and causes reduction in the number of chloroplastids. Wax coatings are also characteristic of many salt-loving plants. Lack of sufficient water or soil nutrients results in the dwarfing and hardening of the tissues, often followed by general chlorosis but without morphogenic changes. The dimorphism of certain plants when grown under differing environmental conditions is well known, but is in no sense comparable to a diseased or other deranged condition. Changes in metabolism also may be caused directly by soil or climatic conditions. All these changes, however, in the main, are general changes affecting the plant tissues as a whole or tending to affect all similar tissues of the plant alike.

In pecan rosette profound alterations and derangements in metabolism, anatomy, and morphogenesis occur together in great complexity. Different types of tissue derangement are found in the same leaf. Reduction and increase in the number of cell divisions, tissue

differentiation and lack of tissue differentiation, hypotrophy and hypertrophy of cells may all occur together within an area only a few millimeters in diameter. There seem to be focal centers out from which these alterations spread, and the resulting abnormal development appears to be controlled from these centers rather than by the normal morphogenic forces. The factors controlling morphogenesis as related to cell differentiation, to development of tissues in diseased areas, and to general pattern of leaf are profoundly altered. No less far-reaching are the derangements in metabolism evidenced by the altered assimilation and translocation of starch.

Pecan rosette frequently appears first on the tip leaves of a single branch and seems as likely to affect a part of the tree first as to occur at once over the whole top.

Careful field observations have given no evidence of varietal differences in susceptibility or resistance to pecan rosette. This same statement would apply equally well to most infectious chloroses.

Fertilizer and transplanting experiments and field observations indicate that rosette is affected, at least indirectly, by soil and climatic conditions, but similar relations are exhibited by chloroses of known infectious nature as well as by many diseases of bacterial or fungous origin. Furthermore, great reliance is not to be placed upon the results of plat soil experiments unless such results are unusually definite, or unless in a large number of similar tests the data all point in the same direction.

In view of the refractory attitude exhibited toward grafting and cross-inoculating experiments by certain of the infectious chloroses it is considered that this type of experimentation has not yet given a conclusive answer to the question of possible infectivity in pecan rosette. In the early experiments a small portion of the diseased buds developed the disease, though in no larger percentage than in contiguous nursery trees worked with supposedly healthy buds in the ordinary commercial propagation. These experiments need repetition on a large scale under controlled conditions and with extreme care in selection both of diseased and healthy buds and stocks. Moreover, the possibility of insect transmission has not been touched upon from the standpoint of experiment.

The disease has not been definitely and experimentally caused by a set of known conditions. Though it is more prevalent and severe under certain environmental conditions, it occurs to some extent in practically every soil type where the tree has been observed, with the possible exception of swamp land. Under these conditions the tree makes very little growth and presents a starved and stunted appearance followed by a general form of chlorosis bearing no resemblance to rosette. Ultimate proof of the cause must account for all cases of the disease.

It is difficult to explain on the soil hypothesis why only a part of a tree may be diseased and why when two trees of the same age stand within a few inches or a few feet of each other the one may remain perfectly normal and vigorous while the other is stunted and dying back with rosette. The recovery of diseased trees when transplanted in the north on the other hand is also difficult to explain, but no more so than the apparent recovery of potatoes from mosaic when carried from Maine to Colorado or tobacco mosaic under certain relations of light or temperature. As previously mentioned, Baur has clearly demonstrated that the contagium of abutilon mosaic is readily killed by subjection to certain environmental conditions such as the withdrawal of light. He found that cutting out the yellow areas as they developed also finally brought recovery. Here, as in many parasitic diseases both of plants and of animals, though the contagium may be carried to remote parts of the body, it is only in certain definite locations and under certain definite conditions that it can reproduce itself and initiate lesions in the host.

If pecan rosette is due to some chemical compound brought in from the soil in harmful quantities one would expect the tissues along the veins to be first and most profoundly affected and that the result would be evident over the whole tree at about the same time. Furthermore, if the yellow mottling is interpreted as due not to a cause operating from the focal centers of the spots but to a lack of sufficient soil nutrients or water brought in by the veins, how are to be explained the lack of chlorosis along the leaf margins and the abnormally increased growth at the periphery of the spots?

It is true that the local application of purely physical or chemical stimuli may locally cause cells to enlarge or proliferate, and their application in lethal quantities may result in injury and final death without the intervention of any parasitic organism, as witness, for example, the more recent experiments of Dr. Erwin F. Smith (74) in the production of plant overgrowths without the intervention of any parasite. However, as in any cytological or embryological study, it is not the single section taken by itself that tells the story, but the sequence of one following the other, the whole series fitting together in an orderly manner to build up the complete picture, so in the chloroses of plants it is not the mere fact of chlorophyll disintegration that will show the type of disturbance present, or that will eventually lead to the determination of the cause in any particular case, but the whole series of events and appearances concerned in the production and manifestation of the derangement.

It is probable that all effects of parasites upon their hosts, when reduced to their ultimate reactions, may be explained in terms of physics and chemistry. It is in the regulation of these physical

and chemical reactions and stimuli, and in their application in a particular manner and at a particular time and place, that the complexity of the final manifestations of infectious diseases differs from the more simply induced changes in metabolism and structure. It is this regulatory effect and this extreme complexity of reaction which make many infectious diseases so difficult to induce by artificial means.

If causes may in any measure be judged from their effects, the histological and cytological evidence points to the cause of pecan rosette as being similar in its general nature to the ultimate causes of the infectious chloroses. Whether in this particular disease the factors responsible for alterations in the normal structure and metabolism must be introduced into the plant from without, or whether they originate within the plant itself, is a question yet to be answered; but whatever the ultimate solution of the problem may be, the cause will undoubtedly not be found in any simple soil or water relation.

So far as worked out, the infectious chloroses in general exhibit, like pecan rosette, a simultaneous and deep-seated derangement both in morphogenesis and metabolic processes. Structural derangements in diseased leaves may show abrupt local change. That is, in many cases, entirely different types of tissue derangement, such as reduction in size of cells and number of cell divisions or enlargement of cells and increased number of cell divisions, may occur side by side, not only in the same leaf but even in the same part of the leaf. Along with these structural changes occur fundamental functional derangements concerned with the assimilation and translocation of carbohydrates and with nitrogen metabolism. As is well stated by True and Hawkins (79) in considering spinach blight:

It would seem to be indicated that the cause of carbohydrate accumulation should be sought in the deeper lying metabolic processes in connection with which carbohydrates are utilized. . . . Accumulation is due not to a breakdown of digestion but to some partial failure in the subsequent metabolic processes in connection with which carbohydrates are used.

Moreover, not only restriction in chlorophyll development occurs, but often abnormal and irregular groupings and a reduction in size and number of chloroplasts. In the later stages disintegration of the plastids and other cell contents often follows, and finally a shriveling of the entire cell ensues.

It is typical of the group of infectious chloroses that only meristematic tissues are morphogenetically affected. There is always a rather definite incubation period for each disease, and external signs of the disease gradually progress from the point of entry of the contagium. In some instances the contagium appears not to reach all parts of the plant, as in the case of potato plants secondarily infected with mosaic or leaf-roll where often only a part of the

tubers give rise to diseased progeny. Furthermore, the fact that many of these diseases are transmissible by insects shows them to be entirely different in nature from those chloroses due to soil or climatic conditions. In some of these diseases where the insect relations have been most carefully worked out it is indicated that a definite incubation period must also elapse after feeding upon a diseased plant before an insect becomes infective.

Except in the most general way, the infectious chloroses exhibit no pattern as related to the leaf. The factors controlling morphogenesis of the leaf in many cases seem to have run riot. In the mosaic type the spots, irregular in themselves, are also irregularly distributed over the surface of the leaf. In many cases, it is true, they avoid the larger veins, but in other instances they are distributed irrespective of venation.

There is nothing to show a difference in kind between those mosaics transmissible by expressed plant juices and those transmitted only by grafting, such as the infectious mosaic of *Abutilon*. The causal contagium in the latter case may be compared to a more obligate parasite which is greatly restricted in the conditions necessary to its life activities and reproduction.

The fact that later investigation has shown some of the filterable contagium diseases to be due to microorganisms is at least presumptive evidence in favor of the organism theory of infectious chloroses. Furthermore, Allard has shown that with a fine enough clay cup it is possible entirely to filter out the infective principle from the expressed juices of tobacco plants affected with mosaic.

The crucial difference, however, lies in the power of self-reproduction possessed by the contagia of all the infectious chloroses. To give a concrete example, starting with a mosaic-diseased tobacco plant and in each case using a drop of the expressed plant juice diluted 1 to 1,000 in water, it is possible to cause the disease in an indefinite series of plants successively inoculated one from the other at proper intervals, and the juice from the last of the series will possess as high a power of infection as that from the first. In a case like this it might be mathematically shown that if reproduction had not taken place a drop from the last plant of the series must contain less than one molecule of the originally injected material. No such power of self-reproduction has ever been demonstrated for a definite chemical compound. The true enzymes are formed by living organisms in response to certain stimuli and have never been shown to be capable of self-reproduction.

Assuming the contagia of infectious chloroses to be nonliving substances, their effects may be compared up to a certain point with various phenomena of bacterial toxins and immunization. However, the fact of reproduction in these contagia is in no way elucidated by

any such comparison. Diphtheria toxin, for instance, if injected into a susceptible host may cause all essential signs of the disease, but it takes living bacteria to produce more of the toxin so that the disease may be transmitted down the line through a successive series of individuals.

On the other hand, the "Contagium vivum fluidum" theory of Beijerinck (17) in some modification is at least worthy of serious consideration as a working hypothesis. It is not impossible that decomposition processes may be propagated by methods entirely unlike reproduction by division as known in living organisms and so as to imitate self-reproduction. If some such course of events could be demonstrated it would perhaps explain the known facts, including the gradual progress of the disease from the point of entry, equally as well as the organism theory. However, though it is well to keep an open mind on all questions still in the realm of theory, no such course of events is yet known to chemistry. On the other hand, most of the known facts concerning the so-called filterable virus diseases, so it seems to the writer, conform to the known results of invasion by parasitic organisms.

SUMMARY.

As a class, the chloroses due to soil or atmospheric conditions are rather general effects which are more or less comparable to starvation, overfeeding, or direct poisoning. There are not the profound or strictly localized derangements in both metabolic and anatomical development, and it is a question in regard to many of these phenomena whether, in the restricted sense, they should be regarded as diseases at all.

In the specific chlorotic diseases of an infectious nature fundamental derangements in both physiological and structural development are simultaneously brought about. Although all effects of parasite upon host when reduced to their ultimate reactions are probably to be explained in terms of physics and chemistry, it is in the regulatory effect and in the extreme complexity that these and many other infectious diseases differ from the direct effects of nonliving substances.

The histological and cytological evidence suggests that pecan rosette in its specific sequence of signs and in the complexity of the structural and physiological derangements bears far more similarity to the known infectious chloroses than to those caused by soil or climatic conditions. Whether in this particular disease the factors responsible for alterations in the normal structure and metabolism must be introduced into the plant from without, or whether they originate within the plant itself, is a question yet to be answered; but whatever the ultimate solution of the problem the cause will undoubtedly not be found in any simple soil or water relation.

LITERATURE CITED.

- (1) ALLARD, H. A.
1914. The mosaic disease of tobacco. U. S. Dept. Agr. Bul. 40, 33 p., 7 pl.
- (2) 1915. Effect of dilution upon the infectivity of the virus of the mosaic disease of tobacco. *In Jour. Agr. Research*, v. 3, no. 4, p. 295-299.
- (3) 1915. Distribution of the virus of the mosaic disease in capsules, filaments, anthers, and pistils of affected tobacco plants. *In Jour. Agr. Research*, v. 5, no. 6, p. 251-256, pl. 23.
- (4) 1916. Some properties of the virus of the mosaic disease of tobacco. *In Jour. Agr. Research*, v. 6, no. 17, p. 649-674, pl. 91. Literature cited, p. 673-674.
- (5) 1916. The mosaic disease of tomatoes and petunias. *In Phytopathology*, v. 6, no. 4, p. 328-335, 2 fig.
- (6) 1917. Further studies of the mosaic disease of tobacco. *In Jour. Agr. Research*, v. 10, no. 12, p. 615-632, pl. 63.
- (7) 1918. Effect of various salts, acids, germicides, etc., upon the infectivity of the virus causing the mosaic disease of tobacco. *In Jour. Agr. Research*, v. 13, no. 12, p. 619-637.
- (8) 1918. The mosaic disease of *Phytolacca decandra*. *In Phytopathology*, v. 8, no. 2, p. 51-54, 2 fig.
- (9) AMELUNG, ERICH.
1893. Ueber mittlere Zellengrößen. *In Flora*, Bd. 77, Heft 3, p. 176-207.
- (10) BALL, E. D.
1909. Some insects injurious to truck crops. The leafhoppers of the sugar beet and their relation to the "curly-leaf" condition. *In U. S. Dept. Agr., Bur. Ent. Bul. 66*, pt. 4, p. 33-52, pl. 1-4. Bibliographical references, p. 48.
- (11) BAUB, ERWIN.
1904. Zur Aetiologie der infektiösen Panachierung. *In Ber. Deut. Bot. Gesell.*, Bd. 22, Heft 8, p. 453-460.
- (12) 1906. Ueber die infektiöse Chlorose der Malvaceen. *In Sitzber. K. Preuss. Akad. Wiss.*, Jahrg. 1906, Stück 1, p. 11-29.
- (13) 1906. Weitere Mitteilungen ueber die infektiöse Chlorose der Malvaceen und über einige analoge Erscheinungen bei *Ligustrum* und *Laburnum*. *In Ber. Deut. Bot. Gesell.*, Bd. 24, Heft 8, p. 416-428.
- (14) 1907. Ueber infektiöse Chlorosen bei *Ligustrum*, *Laburnum*, *Fraxinus*, *Sorbus* und *Ptelea*. *In Ber. Deut. Bot. Gesell.*, Bd. 25, Heft 7, p. 410-413.
- (15) 1907. Untersuchungen ueber die Erbliehkeitsverhältnisse einer nur in Bastardform lebensfähigen Sippe von *Antirrhinum majus*. *In Ber. Deut. Bot. Gesell.*, Bd. 25, Heft 8, p. 442-454.
- (16) 1910. Pfropfbastarde. *In Biol. Centbl.*, Bd. 30, No. 15, p. 497-514, 7 fig.

- (17) BEIJERINCK, M. W.
1898. Ueber ein Contagium vivum fluidum als Ursache der Fleckenkrankheit der Tabaksblätter. *In* Verhandl. K. Akad. Wetensch. Amsterdam, sect. 2, deel 6, no. 5, 21, 1 p., 2 col. pl.
- (18) BLAKE, M. A., COOK, MEL T., and SCHWARZE, C. A.
1917. Studies on peach yellows and little peach. (Abstract.) *In* Phytopathology, v. 7, no. 1, p. 76-77.
- (19) BRANDES, E. W.
1919. The mosaic disease of sugar cane and other grasses. U. S. Dept. Agr. Bul. 829, 26 p., 5 fig. 1 col. pl.
- (20) 1920. Artificial and insect transmission of sugar-cane mosaic. *In* Jour. Agr. Research, v. 19, no. 3, p. 131-138. Literature cited, p. 138.
- (21) 1920. Mosaic disease of corn. *In* Jour. Agr. Research, v. 19, no. 10, p. 517-522, pl. 95-96.
- (22) CLAUSEN.
1910. Die Dörrfleckenkrankheit des Hafers. *In* Mitt. Deut. Landw. Gesell., Jahr 25, Stück 44, p. 631-639, 3 fig.
- (23) CLEMENTS, EDITH SCHWARTZ.
1905. The relation of leaf structure to physical factors. *In* Trans. Amer. Micros. Soc., v. 26, 1904, p. 19-102, 9 pl. Bibliography, p. 93-94.
- (24) COLEMAN, LESLIE C.
1917. Spike disease of sandal. Dept. Agric. Mysore [India] Bul. Mycol. ser., no. 3, 52 p., [1], 18 pl.
- (25) CONKLIN, EDWIN G.
1912. Body size and cell size. *In* Jour. Morphol., v. 23, no. 1, p. 159-188, 12 fig. Literature cited, p. 187-188.
- (26) CRITTENDEN, C. G.
1918. Pecan diseases other than scab. *In* Ga. State Bd. Ent. Bul. 49, p. 44-48, pl. 12-13.
- (27) DICKINSON, THOMAS.
1814. Observations on the disease in the potato, generally called the curl; pointing out the most probable method of preventing it; with an account of the results of a few experiments made on the subject. *In* Mem. Caledonian Hort. Soc., v. 1, p. 49-64, 1 col. pl.
- (28) DOOLITTLE, S. P.
1916. A new infectious mosaic disease of cucumber. *In* Phytopathology, v. 6, no. 2, p. 145-147.
- (29) 1920. The mosaic disease of cucurbits. U. S. Dept. Agr. Bul. 879, 69 p., 10 pl. (3 col.). Literature cited, p. 68-69.
- (30) ——— and GILBERT, W. W.
1918. Further notes on cucumber mosaic disease. Abstract *in* Phytopathology, v. 8, no. 2, p. 77-78.
- (31) 1919. Seed transmission of cucurbit mosaic by the wild cucumber. *In* Phytopathology, v. 9, no. 8, p. 326-327.
- (32) ENSIGN, M. R.
1919. Venation and senescence of polyembryonic citrus plants. *In* Amer. Jour. Bot., v. 6, no. 8, p. 311-329, 6 fig. Bibliography, p. 329.

- (33) FAWCETT, H. S.
1910. Pecan diseases. *In Fla. Agr. Exp. Sta. Ann. Rpt.*, 1908/09, p. ix-lxii.
- (34) FISCHER, C. E. C.
1918. Cause of the spike disease of sandal (*Santalum album*). *In Indian Forester*, v. 44, no. 12, p. 570-575.
- (35) GILE, P. L.
1911. Relation of calcareous soils to pineapple chlorosis. *Porto Rico Agr. Exp. Sta. Bul.* 11, 45 p., 2 pl. (1 col.).
- (36) 1916. Chlorosis of pineapples induced by manganese and carbonate of lime. *In Science*, n. s. v. 44, no. 1146, p. 855-857.
- (37) ——— and AGETON, C. N.
1914. Chlorosis of sugar cane. *In Porto Rico Agr. Exp. Sta., Ann. Rpt.* 1912/13, p. 13-14.
- (38) ——— and CARRERO, J. O.
1915. Lime-induced chlorosis. *In Porto Rico Agr. Exp. Sta. Ann. Rpt.*, 1914, p. 15-16.
- (39) HANSON, HERBERT C.
1917. Leaf-structure as related to environment. *In Amer. Jour. Bot.*, v. 4, no. 9, p. 533-560, 21 fig. Bibliography, p. 559-560.
- (40) HEINTZEL, KURT.
1900. Contagiöse Pflanzenkrankheiten ohne Microben unter besonderer Berücksichtigung der Mosaikkkrankheit der Tabaksblätter. 46, 1 p., 1 pl. Erlangen. Inaug.-Diss.
- (41) HUNGER, F. W. T.
1903. Bemerkung zur Woods'schen Theorie ueber die Mosaikkkrankheit des Tabaks. *In Bul. Inst. Bot. Buitenzorg*, no. 17, p. 1-9.
- (42) IWANOWSKY, D.
1892. Ueber zwei Krankheiten der Tabakspflanze. *In Land- und Forstwirthschaft*, 1892. Original in Russian, not seen. Abstract in *Bot. Centbl.*, Beihefte, Jahrg. 3, p. 266-268. 1893.
- (43) JAGGER, I. C.
1916. Experiments with the cucumber mosaic disease. *In Phytopathology*, v. 6, no. 2, p. 148-151.
- (44) 1918. Hosts of the white pickle mosaic disease of cucumber. *In Phytopathology*, v. 8, no. 1, p. 32-33.
- (45) JOHNSON, GEORGE W.
1847. The Potato; its Culture, Uses and History. iv, 181 p. 1 col. pl. London and Winchester, England. *Gardeners' Monthly*, vol. 1.
- (46) JOHNSON, M. O.
1916. The spraying of yellow pineapple plants on manganese soils with iron sulphate solutions. *Hawaii Agr. Exp. Sta. Press Bul.* 51, 11 p., 4 fig.
- (47) KONING, C. J.
1899. Die Flecken- oder Mosaikkkrankheit des holländischen Tabaks. *In Ztschr. Pflanzenkrank.*, Bd. 9, Heft 2, p. 65-80, 2 fig.
- (48) KÜSTER, ERNST.
1913. Ueber Zonenbildung in kolloidalen Medien. x, 111 p., 53 fig. Jena. (Beiträge zur Entwicklungsmechanischen Anatomie der Pflanzen, Heft 1.)

- (49) MCCLINTOCK, J. A., and SMITH, LOREN B.
1918. True nature of spinach blight and relation of insects to its transmission. *In Jour. Agr. Research*, v. 14, no. 1, p. 1-60, 1 fig., pl. 1-11, A (col.).
- (50) McMURRAN, S. M.
1919. Pecan rosette in relation to soil deficiencies. U. S. Dept. Agr. Bul. 756, 11 p., 4 fig.
- (51) MATZ, JULIUS.
1918. Diseases and insect pests of the pecan. Fla. Agr. Exp. Sta. Bul. 147, p. 133-163, fig. 45-73.
- (52) MAYER, ADOLF.
1886. Ueber die Mosaikkrankheit des Tabaks. *In Landw. Vers. Stat.*, Bd. 32, p. 451-467, pl. 3.
- (53) MAZÉ, PIERRE.
1911. Sur la chlorose expérimentale du maïs. *In Compt. Rend. Acad. Sci. [Paris]*, t. 153, no. 19, p. 902-905.
- (54) MILLER, H. K.
1916. Rosette of the pecan. *In Proc. Nat. Nut Growers' Assoc.* v. 15, p. 57-60.
- (55) NISHIMURA, MAKOTO.
1918. A carrier of the mosaic disease. *In Bul. Torrey Bot. Club*, v. 45, no. 6, p. 219-233, pl. 7. Literature cited, p. 232-233.
- (56) ORTON, W. A., and RAND, FREDERICK V.
1914. Pecan rosette. *In Jour. Agr. Research*, v. 3, no. 2, p. 149-174, 1 fig., pl. 24-28.
- (57) PALLADIN, VLADIMIR L.
[1918] Plant physiology . . . authorized English ed. based on the German translation of the 6th Russian ed. and on the 7th Russian ed. (1914), edited by Burton Edward Livingston. xxv, 320 p., 173 fig. Philadelphia. A classified list of books, p. xiii-xvi.
- (58) PENHALLOW, D. P.
1882-83. Peach yellows. *In Houghton Farm (Orange Co., N. Y.) Exp. Dept. [Papers]*, ser. 3, no. 1/2, p. 23-45, 4 col. pl. 1882; no. 3, p. 51-64. 1883.
- (59) PETHYBRIDGE, GEORGE H.
1912. Investigations on potato diseases. Third report. *In Dept. Agr. and Tech. Instr. Ireland Jour.*, v. 12, no. 2, p. 334-360, 3 pl.
- (60) QUANJER, H. M.
1913. Die Nekrose des Phloëms der Kartoffelpflanze, die Ursache der Blattrollkrankheit. *In Meded. Rijks Hoogere Land-, Tuinen Boschbouwschool [Wageningen]*, deel 6, afl. 2, p. 41-80, pl. 2-9.
- (61) 1920. The mosaic disease of the Solanaceæ, its relation to the phloem-necrosis, and its effect upon potato culture. *In Phytopathology*, v. 10, no. 1, p. 35-47, 14 fig. Literature cited, p. 47. (Essentially a reprint of the English summary, and of part of the figures and bibliography of (62) below.)

- (62) QUANJER, H. M., and others.
1919. De mosaiekziekte van de Solanaceeën hare verwantschap met de phloeemnecrose en hare betkeekenis voor de aardappelcultuur. *In* Meded. Rijks Hogere Land-, Tuin- en Boschbouwschool [Wageningen], deel 17, aff. 1/3, p. 1-90, 8 pl. (1-2 col.). Litertuur, p. 67-70. Summary [in English], p. 71-74.
- (63) REDDICK, DONALD, and STEWART, VERN B.
1918. Varieties of beans susceptible to mosaic. *In* *Phytopathology*, v. 8, no. 10, p. 530-534.
- (64) 1919. Transmission of the virus of bean mosaic in seed and observations on thermal death-point of seed and virus. *In* *Phytopathology*, v. 9, no. 10, p. 445-450.
- (65) SCHULTZ, E. S., and FOLSOM, DONALD.
1920. Transmission of the mosaic disease of Irish potatoes. *In* *Jour. Agr. Research*, v. 19, no. 7, p. 315-338, pl. 49-56.
- (66) 1921. Leaf-roll, net-necrosis, and spindling-sprout, of the Irish potato. *In* *Jour. Agr. Research*, v. 21, no. 1, p. 47-80, pl. 1-12. Literature cited, p. 78-80.
- (67) ——— HILDERBRANDT, F. MERRILL, and HAWKINS, LON A.
1919. Investigations on the mosaic disease of the Irish potato. Preliminary paper. *In* *Jour. Agr. Research*, v. 17, no. 6, p. 247-274, pl. 25-30, A-B (col.). Literature cited, p. 272-273.
- (68) SHAW, HARRY B.
1910. The curly-top of beets. U. S. Dept. Agr., Bur. Plant Indus. Bul. 181, 46 p., 9 fig., 9 pl. Bibliography, p. 37-40.
- (69) SMITH, ERWIN F.
1888. Peach yellows: a preliminary report. U. S. Dept. Agr., Div. Bot. Bul. 9, 254 p., 37 pl. (32-37 col.), 9 col. fold. [maps].
- (70) 1891. Additional evidence on the communicability of peach yellows and peach rosette. U. S. Dept. Agr., Div. Veg. Path. Bul. 1, 65 p., 38 pl.
- (71) 1893. Experiments with fertilizers for the prevention and cure of peach yellows, 1889-92. U. S. Dept. Agr., Div. Veg. Path. Bul. 4, 197 p., 33 pl. (6 fold.).
- (72) 1893. Additional notes on peach rosette. *In* *Jour. Mycol.*, v. 7, no. 3, p. 226-232.
- (73) 1898. Notes on the Michigan disease known as "little peach." An address before the Saugatuck and Ganges pomological society. 12 p. Reprinted from Fenville (Mich.) Herald, Oct. 15, 1898.
- (74) 1920. An Introduction to Bacterial Diseases of Plants. xxx, 688 p., 453 fig., 1 pl. Philadelphia and London. Bibliographies at end of most of the chapters.
- (75) STEWART, V. B., and REDDICK, DONALD.
1917. Bean mosaic. (Abstract.) *In* *Phytopathology*, v. 7, no. 1, p. 61.
- (76) TAUBENHAUS, J. J.
1914. The diseases of the sweet pea. Del. Agr. Exp. Sta. Bul. 106, 93 p. [2], 43 fig., tab. 8 (fold.). References, p. 88-93.

- (77) TENOPYE, LILLIAN A.
1918. On the constancy of cell shape in leaves of varying shape. *In* Bul. Torrey Bot. Club, v. 45, no. 2, p. 51-76, 1 fig. Literature cited, p. 75-76.
- (78) TRANSEAU, EDGAR N.
1904. On the development of palisade tissue and resinous deposits in leaves. *In* Science, n. s. v. 19, no. 492, p. 866-867.
- (79) TRUE, RODNEY H., and HAWKINS, LON A.
1918. Physiological studies of normal and blighted spinach. Carbohydrate production in healthy and in blighted spinach. *In* Jour. Agr. Research, v. 15, no. 7, p. 381-384.
- (80) TSCHIRCH, ALEXANDER.
1900. Die Harze und die Harzbehälter. Historisch-Kritische und Experimentelle in Gemeinschaft mit zahlreichen Mitarbeitern ausgeführte Untersuchungen, viii, 417 p., 6 pl. (6 col.) Leipzig.
- (81) VENKATARAMA AYYAR, K. R.
1918. Is spike disease of sandal (*Santalum album*) due to an unbalanced circulation of sap? *In* Indian Forester, v. 44, no. 7, p. 316-324, pl. 19.
- (82) WARMING, EUGENIUS.
1909. Oecology of Plants; an Introduction to the Study of Plant-Communities. . . . Prepared for publication in English by Percy Groom . . . and Isaac Bayley Balfour. xi, 422 p. Oxford, England. Literature, p. 374-405.
- (83) WAYNICK, DEAN DAVID.
1918. The chemical composition of the plant as further proof of the close relation between antagonism and cell permeability. *In* Univ. Cal. Pub. Agr. Sci., v. 3, no. 8, p. 135-242, 26 fig., pl. 13-24.
- (84) WOODS, ALBERT F.
1900. Inhibiting action of oxidase upon diastase. *In* Science, n. s., v. 11, no. 262, p. 17-19.
- (85) 1902. Observations on the mosaic disease of tobacco. U. S. Dept. Agr., Bur. Plant Indus. Bul. 18, 24 p., 6 pl. (1, 2, and 6 col.).

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
25 CENTS PER COPY
▽



Washington, D. C.

May 5, 1922

EXPERIMENTS WITH CEREALS ON THE BELLE FOURCHE EXPERIMENT FARM.

By JOHN H. MARTIN, *Agronomist, Office of Cereal Investigations.*

CONTENTS.

	Page.		Page.
The cereal experiments.....	1	Experiments on dry land—Continued.	
Description of the field station.....	2	Experiments with minor cereals.....	36
Location.....	2	Comparison of grain crops.....	41
History of the region.....	3	Experiments with flax.....	42
Soil.....	4	Experiments on irrigated land.....	45
Native vegetation.....	4	Experiments with wheat.....	46
Climatic conditions.....	5	Experiments with oats.....	52
Experimental methods.....	11	Experiments with barley.....	56
Preparation of the land.....	11	Experiments with minor cereals.....	59
Plat experiments.....	11	Experiments with grain mix- tures.....	62
Nursery experiments.....	12	Comparison of grain crops.....	64
Experiments on dry land.....	13	Experiments with flax.....	65
Experiments with wheat.....	13	Tillage experiments.....	69
Experiments with oats.....	27	Summary.....	70
Experiments with barley.....	32		

THE CEREAL EXPERIMENTS.¹

The investigations with cereals on the Belle Fourche Experiment Farm have consisted chiefly of varietal, rate-of-seeding, date-of-seeding, and depth-of-seeding experiments, and the improvement of cereal varieties by the head-selection method. From 1907 to 1911 the

¹ The experiments here reported were conducted on the Belle Fourche Experiment Farm, near Newell, S. Dak., during the 13-year period from 1907 to 1919, inclusive. The experiments were in cooperation with the Office of Western Irrigation Agriculture of the Bureau of Plant Industry, by whom the farm is operated. On April 1, 1912, the cooperative agreement between the Office of Cereal Investigations of the Bureau of Plant Industry and the South Dakota Agricultural Experiment Station was expanded to include the work at Newell. Mr. Cecil Salmon was in charge of the experiments from 1907 to 1913, inclusive; Mr. E. M. Johnston and the writer in 1914; the writer in 1915, 1916, 1917, and part of 1918; and Mr. A. D. Ellison in 1919. Valuable assistance during this period has been rendered by Mr. Beyer Aune, farm superintendent, and Mr. O. R. Mathews, assistant in dry-land agriculture, of the Belle Fourche Experiment Farm. Acknowledgment is here made of the assistance of those mentioned above.

work was conducted wholly on dry land, but in 1912 a considerable portion of the farm was put under irrigation, and experiments with cereals on irrigated land were begun. The results of these investigations have been reported in part in several previous bulletins of the United States Department of Agriculture and the South Dakota Agricultural Experiment Station.

The results obtained from the experiments on the dry land up to and including 1913 have been published in detail.² The work was discontinued at the close of the season of 1919 and all of the important results are published here in order to bring the data up to date and to make the unpublished results from all experiments available. Owing to the widely varying climatic conditions, the yields of the grains show large fluctuations in different seasons. Most of the experiments here reported, however, have been conducted for a sufficiently long period to show quite definitely which are the best varieties and the best cultural methods for growing the various cereals in this region. The results are applicable to a large part of western South Dakota and adjacent portions of northeastern Wyoming, southeastern Montana, and southwestern North Dakota, especially on the heavier types of soil.

The average yields of wheat, oats, and barley obtained on dry land are not large, but might be profitable if seasonal conditions were more uniform. Low yields have been obtained in several years and failures of a part or all of the crops in others. High yields were obtained in 1915 and fairly high yields of some crops in 1908, 1909, and 1918. Grain growing alone is not likely to be successful in western South Dakota, but if carried on in conjunction with stock raising will be profitable some years. Wheat, oats, and barley are more successful than other small grains.

The average yields of the grains on irrigated land are not large. Fair yields of most grain crops were obtained each year and good yields were produced from time to time, so that grain growing has proved successful, especially in rotations with other crops.

DESCRIPTION OF THE FIELD STATION.

LOCATION.

The Belle Fourche Experiment Farm consists of 360 acres located near the center of the Belle Fourche reclamation project in western South Dakota, about 30 miles northeast of the Black Hills. The farm is about 24 miles northeast of Bellefourche and 2 miles northwest of Newell. The latitude is about 44° 43' 45" N., and the longitude 103° 26' 15" W. The altitude is almost 2,900 feet. Most of

² Salmon, Cecil. Cereal investigations on the Belle Fourche Experiment Farm. U. S. Dept. Agr. Bul. 297, 41 p., 12 fig. 1915.

the farm has been under irrigation since 1912, but a portion of it above the irrigation ditch has been used for dry-land experiments. The topography of the farm and of the surrounding country is rolling, affording good drainage, but making irrigation difficult or accompanied by a considerable waste of irrigation water.

A view of the buildings on the Belle Fourche Experiment Farm in 1919 is shown in figure 1.

HISTORY OF THE REGION.

Prior to the discovery of gold in the Black Hills in 1875, western South Dakota was almost undisturbed by white men. Since the early eighties, however, this has been an important grazing region. Farming was confined to the river valleys and the lands adjacent to the Black Hills. The stockmen mowed the wild grasses which grew



FIG. 1.—Buildings on the Belle Fourche Experiment Farm.

in the low lands on the prairies and fed the hay during the winter to cattle and sheep.

Homesteading in the dry-land region about Newell began about 1908, and within the next three years most of the public land had been taken up. Following a series of dry years, most of the homesteads were abandoned, and to-day the region is devoted very largely to grazing. Some dry farming³ is practiced, especially in the better favored localities, frequently in connection with stock raising. Along the border of and within the Black Hills dry farming continues to be a successful practice. The Belle Fourche reclamation project has been developed since about 1911. A considerable acreage of cereals is grown each year under irrigation on this and older adjacent irrigation projects.

³ For a detailed account of dry-farming methods in western South Dakota, see U. S. Dept. Agr., Farmers' Bulletin 1163, entitled "Dry Farming in Western South Dakota," by O. R. Mathews, 16 p. 1920.

On newly irrigated land small grains or flax usually are sown for a cash crop, and on old irrigated land a considerable acreage of these crops is grown in rotations following a cultivated crop or as a nurse crop for alfalfa.

SOIL.

The soil of the Belle Fourche Experiment Farm and of the surrounding section is a heavy, stiff clay, or gumbo, classified by the Bureau of Soils as Pierre clay.⁴ This soil occupies about one-third of the area of western South Dakota.

It contains about 35 per cent of clay, 43 per cent of silt, 13 per cent of very fine sand, and only a small quantity of humus. The soil is of residual origin and contains considerable quantities of calcium, magnesium, and sodium salts. Alkali is a problem only in seeped areas.

The soil when wet is exceedingly sticky and is almost impervious to water.⁵ Upon drying, it checks rapidly, later forming large cracks which permit the entrance of water. The soil can not be plowed when wet and is difficult to plow when dry, but disking and harrowing are comparatively easy if done at the proper time. Land plowed in the fall when dry becomes quite mellow in the spring from the alternate contraction and expansion caused by temperature changes during the winter. The soil contains ample quantities of plant food and with sufficient rainfall is capable of producing large yields of grain.

NATIVE VEGETATION.⁶

The native vegetation of the locality consists largely of western wheat-grass (*Agropyron smithii*, *A. occidentale*) and buffalo grass (*Bulbilis dactyloides*). Grama grass (*Bouteloua oligostachya*) and needle grass (*Stipa comata*) are frequently found. Buffalo grass usually occupies the higher and lighter soils, especially where Pierre clay is the soil type. Western wheat-grass is confined mostly to the lower slopes and bottoms. On bottom lands subject to overflow this grass produces considerable hay of excellent quality.

Weeds, such as sunflower (*Helianthus petiolaris*), gum weed (*Grindelia squarrosa*), goosefoot (*Atriplex volutans*), and wild parsley (*Peucedanum foeniculaceum*), are plentiful. They are particularly abundant following extremely dry seasons, when the grass may be so injured that weeds are practically the only vegetation. Poverty weed (*Iva axillaris*) is of considerable economic importance because of the

⁴ Strahorn, A. T., and Mann, C. W. Soil survey of the Belle Fourche area, South Dakota. In U. S. Dept. Agr., Bur. Soils Field Oper., 9th Rpt., 1907, p. 888. 1909.

⁵ Mathews, O. R. Water penetration in the gumbo soils of the Belle Fourche Reclamation Project. U. S. Dept. Agr. Bul. 447, 12 p., 4 fig. 1916.

⁶ Adapted from U. S. Dept. Agr. Bul. 297, p. 3. 1915.

difficulty of eradicating it in cultivated fields. This plant commonly is called gumbo weed in this locality because it is found usually on the more impervious soils of the Pierre clay type.

CLIMATIC CONDITIONS.

PRECIPITATION.

The precipitation at Newell is very similar to that of most of the northern and western portion of the Great Plains, and especially western North Dakota and South Dakota. Within the Black Hills region the climate is more mild and moist than on the Plains, and

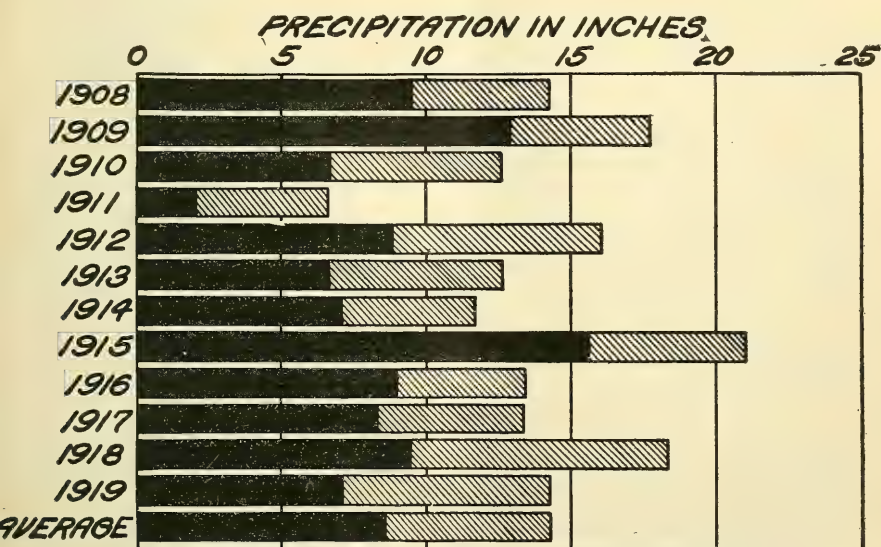


FIG. 2.—Diagram showing the annual and seasonal precipitation at the Belle Fourche Experiment Farm for the 12-year period from 1908 to 1919, inclusive. The solid portion of each bar shows the seasonal precipitation, while the total length of the bar shows the annual precipitation.

the average annual precipitation ranges from 6.64 inches. The Black Hills modify the climate of the immediately surrounding country to a great extent, mainly by increasing the precipitation. This effect extends several miles beyond the outlying foothills. The Belle Fourche Experiment Farm is situated about 25 miles from the foothills and, so far as known, is not influenced to any extent by proximity to the Black Hills.

The total annual precipitation at Newell varied from 6.64 inches in 1911 to 21.02 inches in 1915. The average annual precipitation during the 12 years from 1908 to 1919, inclusive, was 14.31 inches. This is believed to be about the normal for the region around Newell. An average of 8.57 inches, or nearly 60 per cent of the total, occurred during the five months from March to July, inclusive. This is ap-

proximately the growing period for the cereals on dry land at Newell. The seasonal precipitation was a prominent factor affecting the yields of grain. The monthly, seasonal, and annual precipitation recorded in inches at the Belle Fourche Farm from 1908 to 1919, inclusive, is shown in Table I. The seasonal and annual precipitation is also shown graphically in figure 2.

TABLE I.—*Monthly, seasonal, and annual precipitation at the Belle Fourche Experiment Farm, 1908 to 1919, inclusive.*

[Depth of precipitation in inches. T=trace.]

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	March to July, inclusive.	Total.
1908.....	00.20	00.19	01.65	1.16	3.95	1.47	1.26	0.62	0.52	02.10	00.20	00.91	9.49	14.23
1909.....	0.17	0.23	0.19	.84	3.87	5.59	2.45	.55	1.07	.76	.73	1.28	12.94	17.73
1910.....	.73	.70	.93	1.57	1.26	1.51	1.42	1.03	2.92	.27	.11	.10	6.69	12.55
1911.....	.13	.05	.09	.17	.45	.50	.80	1.86	.92	.39	.98	.30	2.01	6.64
1912.....	.24	.10	.71	2.32	2.26	.29	3.20	2.80	3.49	.51	.04	.13	8.78	16.09
1913.....	.57	.24	.99	.25	1.98	3.10	.35	.26	2.38	1.86	.10	.45	6.67	12.53
1914.....	T	1.00	.29	1.09	2.22	2.09	1.34	1.12	.35	1.77	0	.43	7.03	11.70
1915.....	.92	1.01	.16	2.58	2.32	4.74	5.74	.44	1.26	1.25	.43	.17	15.54	21.02
1916.....	.36	.23	.98	.64	3.17	2.19	2.01	2.02	.20	.99	.33	.28	8.99	13.40
1917.....	.92	.74	.27	2.51	3.71	.97	.80	1.67	.35	.46	T	.92	8.26	13.32
1918.....	.99	.64	.81	2.40	1.60	1.17	3.41	2.99	3.08	.22	.15	.85	9.39	18.31
1919.....	.04	.57	.87	2.14	1.14	.35	2.59	1.02	1.20	2.49	1.22	.62	7.09	14.25
Average.....	.44	.48	.66	1.47	2.33	2.00	2.11	1.37	1.48	1.09	.36	.54	8.57	14.31

a From records of the United States Weather Bureau at Vale and Orman, S. Dak.

RELATION OF PRECIPITATION TO YIELDS OF GRAIN.

The limiting factor in crop production at Newell usually has been the moisture supply. Winter grains have been subject to cold injury, so that the yields may depend on several factors. The yields of spring grains, however, are closely associated with the amount and distribution of the rainfall. The precipitation during the growing period is the most important. The amounts and distribution of this seasonal precipitation have largely determined the yields of spring grain on the dry land at Newell. In some seasons, as that of 1912, the rains came too late to benefit the early varieties of grain. In 1910, 1917, and 1919 the lack of moisture during the heading and ripening period caused low yields.

A rain of less than 0.3 inch during the growing season, unless followed or preceded by other rains within 24 hours is of almost no value to grain crops in this section. The moisture from light rains does not penetrate far into the soil and is soon evaporated. In 1911 there was a total precipitation of 2.01 inches during the growing season, March to July, inclusive, but this came in such small and scattered showers that it was useless for crop production. Consequently all grains were a failure that year.

In figure 3 are shown graphically the "useful" seasonal precipitation and the yields of Kubanka durum spring wheat (C. I. No. 1516) during the 12 years from 1908 to 1919, inclusive. The "useful" precipitation shown is the total precipitation in rains of 0.3 inch or more during the period between the emergence and ripening of the Kubanka wheat each year. When the rains occurred during a period of two, three, or four consecutive days the total amounts for the

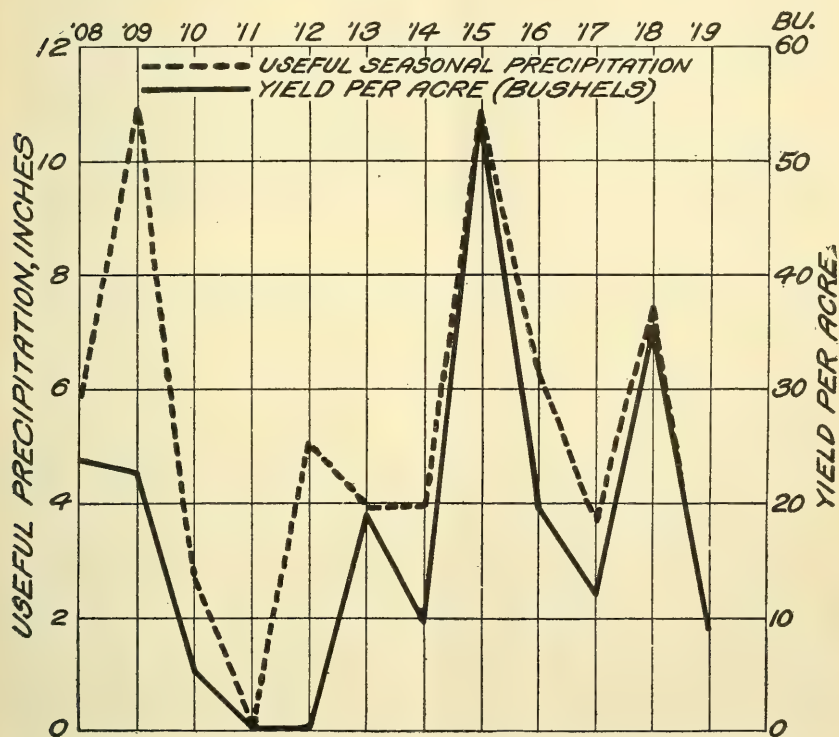


FIG. 3.—Diagram showing the relation between the annual useful seasonal precipitation and the yields per acre of Kubanka durum spring wheat on dry land at the Belle Fourche Experiment Farm for the 12-year period from 1908 to 1919, inclusive. The broken line shows the useful precipitation and the solid line the yields of Kubanka wheat.

period were included even though less than 0.3 inch fell on some of these days. The Kubanka variety of wheat was selected because it was the leading variety, was grown each year, and was not seriously affected by rust.

In figure 3 it will be seen that the yields of Kubanka wheat are closely associated with the useful seasonal precipitation during most of the years. In 1909 and 1914 the wheat was on poorer soil than usual. In 1912 most of the rains came just before the wheat was ripe and too late to be of benefit. The crop was a complete failure in

both 1911 and 1912. The 1913 crop was probably benefited by the abundant late rains in 1912.

EVAPORATION.

The seasonal evaporation probably ranks next in importance to seasonal precipitation among the factors which influence the growth of crops at Newell. The daily evaporation has been recorded at the Belle Fourche Experiment Farm, and the total depth in inches by months from April to September is shown in Table II. The record of evaporation was not kept for the month of March, but at Newell crops ordinarily make little growth during that month and hence this omission is not of importance. The evaporation is determined from a free water surface, the method being that employed at all of the stations where the Biophysical Laboratory of the Bureau of Plant Industry has been cooperating.⁷

TABLE II.—*Monthly evaporation from a free water surface at the Belle Fourche Experiment Farm from April to September of each year, 1908 to 1919, inclusive.*

[Evaporation and precipitation data in inches.]

Year.	Apr.	May.	June.	July.	Aug.	Sept.	Total.	Precipitation.	
								April to September, inclusive.	Ratio to evaporation.
1908.....	5.535	5.917	6.821	8.081	7.866	6.745	40.965	8.98	1:4.6
1909.....	3.657	6.413	5.859	7.698	8.243	5.001	36.871	14.37	1:2.6
1910.....	5.408	5.306	8.975	10.429	7.295	4.302	41.715	9.71	1:4.3
1911.....	4.649	8.302	10.241	10.714	6.682	6.113	46.701	4.70	1:9.9
1912.....	4.849	6.423	8.175	7.980	6.604	3.713	37.744	14.36	1:2.6
1913.....	4.705	4.302	7.046	8.235	8.144	4.707	37.139	8.32	1:4.5
1914.....	3.369	5.133	6.712	8.737	6.966	4.194	35.111	8.21	1:4.3
1915.....	4.454	3.970	4.612	5.352	5.113	3.956	27.457	17.08	1:1.6
1916.....	3.689	5.269	5.138	7.519	5.438	5.429	32.482	10.23	1:3.2
1917.....	2.018	4.704	6.271	9.536	6.983	5.307	34.819	10.01	1:3.5
1918.....	3.278	5.171	6.555	6.482	7.129	3.951	32.566	14.65	1:2.2
1919.....	3.519	6.769	8.904	9.564	8.224	5.122	42.102	8.44	1:5.0
Average.....	4.094	5.640	7.109	8.361	7.057	4.878	37.139	10.76	1:3.5

The average evaporation for the six months from April to September, inclusive, for the 12 years from 1908 to 1919 was 37.139 inches. The lowest total evaporation, 27.457 inches, was recorded in 1915, the year of the greatest rainfall during the same months. The highest total evaporation, 46.701 inches, was recorded in 1911, the year of the lowest seasonal rainfall. Thus the evaporation usually varies inversely with the precipitation, though this is not always the case.

⁷ Briggs, L. J., and Belz, J. O. Dry farming in relation to rainfall and evaporation. U. S. Dept. Agr., Bur. Plant Indus. Bul. 188, p. 16-20. 1911.

The ratio of precipitation to evaporation, also given in Table II, shows the evaporation for the 12 years to be 3.5 times the precipitation. In 1915 the ratio was the narrowest, the evaporation for that year being only 1.6 times the precipitation. In 1911 the ratio was the widest, the evaporation being 9.9 times the precipitation. The ratio of precipitation to evaporation is a fair indication of the seasonal moisture conditions as related to crop yields.

WIND.

The record of wind measurement has been taken at the Belle Fourche Experiment Farm during the growing season since May, 1909. The anemometer stands near the evaporation tank at a height of about 2 feet from the surface of the ground. The average wind velocities in miles per hour during the six months from April to September for the years 1908 to 1919, inclusive, are presented in Table III.

TABLE III.—Average wind velocity at the Belle Fourche Experiment Farm for the six months from April to September, during the 12-year period from 1908 to 1919, inclusive.

[Data in miles per hour.]

Month.	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	Average.
April.....		9.1	9.2	9.2	9.5	6.2	8.2	6.6	7.8	7.8	9.2	7.4	8.2
May.....	8.3	10.1	8.2	11.6	11.1	5.9	7.7	7.4	8.7	5.7	6.6	7.3	8.2
June.....	7.2	6.2	9.3	9.1	7.6	6.8	6.7	6.2	7.3	6.3	4.5	7.7	7.1
July.....	5.0	6.0	7.7	7.9	6.0	5.8	5.0	5.0	5.1	5.3	4.2	6.7	5.8
August.....	6.8	5.6	6.6	7.3	6.9	5.1	5.0	4.1	4.4	4.2	2.8	5.8	5.4
September.....	6.5	5.7	6.2	7.9	7.6	4.5	6.2	5.9	6.2	5.1	2.2	5.5	5.8
Average.....	6.8	7.1	7.9	8.8	8.1	5.7	6.5	5.9	6.6	5.7	4.9	6.7	6.8

The average wind velocity during this period was 6.8 miles per hour. The highest average wind velocity, 8.8 miles per hour, was recorded in 1911, while the lowest, 4.9 miles per hour, was observed in 1918. The velocity during April, May, and June was considerably higher than in July, August, and September. The velocity of the wind has a decided influence upon the crops. The evaporation from the surface of the soil or plant is greatly increased by wind. Hot winds, such as occurred in 1914 and 1917, caused the cereal plants to be prematurely ripened or deadened before the grain was fully developed. Winter wheat was injured somewhat nearly every spring by the blowing of the soil before the spring rains had moistened it. In 1916 some of the spring grains had to be resown because of being blown out after emergence. Owing to the high wind velocity in the early spring, together with the tendency of the soil to blow at that time, it was necessary practically to discontinue summer fallowing as a preparation for grain crops.

TEMPERATURE.

The temperatures at the Belle Fourche Experiment Farm are recorded daily throughout the year by means of maximum and minimum thermometers. During the growing season a thermograph was also used. The mean monthly temperatures in degrees Fahrenheit from 1908 to 1919, inclusive, are shown in Table IV.

TABLE IV.—Mean monthly temperatures (in degrees F.) at the Belle Fourche Experiment Farm during the 12-year period from 1908 to 1919, inclusive.

Month.	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	Average.
January.....		12	18	20	12	13	27	16	5	13	9	29	16
February.....		23	8	22	24	17	14	19	22	11	20	18	18
March.....		32	46	39	19	23	33	21	34	25	40	31	31
April.....	48	38	51	43	47	48	43	52	42	40	41	43	45
May.....	52	52	52	58	55	53	55	51	52	50	55	56	53
June.....	63	66	68	73	66	66	65	58	60	62	69	70	66
July.....	73	70	76	71	70	70	76	64	74	75	69	75	72
August.....	68	75	68	65	68	74	69	66	67	67	70	71	69
September.....	64	61	59	59	52	59	62	56	58	60	56	61	59
October.....	45	46	51	43	45	42	49	50	43	42	50	35	45
November.....	37	31	31	25	38	37	39	34	32	41	31	23	33
December.....	22	10	25	20	28	23	15	25	13	13	25	14	19
Average.....		43	46	45	44	44	46	43	42	42	45	44	44

The average annual mean temperature was 44°. The absolute minimum during this period was -37° F. in January, 1916, and the absolute maximum was 109° F. in July, 1910. The temperature has not been a limiting factor in the yields of most of the spring grains. The grain sorghums and late varieties of proso, however, usually were frosted before fully mature. Winter wheat suffered some injury from low temperatures nearly every year and during the winter of 1917-18 was almost completely destroyed.

TABLE V.—Dates of killing frosts, the last in spring and the first in autumn, at the Belle Fourche Experiment Farm, for each year from 1908 to 1919, inclusive.

Year.	Last frost in spring.		First frost in fall.		Frost-free period.	Year.	Last frost in spring.		First frost in fall.		Frost-free period.
	Date.	Temperature.	Date.	Temperature.			Date.	Temperature.	Date.	Temperature.	
1908.....	May 20	29 °F.	Sept. 26	22 °F.	Days. 129	1915.....	May 21	32 °F.	Sept. 14	31 °F.	Days. 115
1909.....	May 17	26	Sept. 23	31	128	1916.....	May 16	31	Sept. 14	28	121
1910.....	May 23	31	Aug. 25	32	93	1917.....	May 31	30	Oct. 7	20	145
1911.....	May 11	30	Aug. 27	32	107	1918.....	May 21	31	Sept. 18	28	120
1912.....	May 4	32	Sept. 23	32	141	1919.....	June 1	32	Oct. 9	12	130
1913.....	May 6	32	Sept. 24	29	140	Average.	May 18	30.5	Sept. 21	28	126
1914.....	May 13	30	Oct. 5	28	144						

The dates and minimum temperature of the last spring and first autumn frosts each year are shown in Table V. The latest spring

frost was recorded in 1919 on June 1, while the earliest autumn frost was observed in 1910 on August 25. The average frost-free period was 126 days, but this has varied from 93 days in 1910 to 145 days in 1917. The frost-free period is long enough to permit full maturity of all adapted varieties of small grains at Newell.

EXPERIMENTAL METHODS.

PREPARATION OF THE LAND.

Most of the cereals on dry land were sown on either summer fallow or corn ground. Stubble land was usually plowed 6 to 8 inches deep with a disk plow in the fall and left rough over winter. Corn ground was not disturbed until spring, when it usually was double disked and harrowed before seeding. The fall-plowed fallow was not cultivated in the spring until weeds and volunteer grains began to grow, but after this time was kept bare throughout the season by the use of the disk or spring-tooth harrow. Owing to the tendency toward soil blowing early in the spring, which seemed to increase each year after the virgin sod had decayed, it became necessary to conduct most of the experiments on cornland. Yields of grain on summer-fallowed land were more certain and somewhat higher than with other methods of preparation, but were less profitable than on corn ground because of the larger expense for tillage. All of the experiments with winter wheat on the dry land were conducted on fallow.

PLAT EXPERIMENTS.

Nearly all experiments except those in the breeding nurseries and the preliminary varietal experiments were conducted in field plats. These plats in 1908, 1909, and most of them in 1910 were 2 by 8 rods in size, containing one-tenth of an acre. The plats were separated by 5-foot alleys, and the road between each series of plats and the next was either 16.5 or 20 feet wide.

Most of the experiments in 1911 and all of those in 1912 and thereafter were in plats made by sowing a single drill width across an 8-rod series. As the drill was 6 feet wide, this gave a plat of one fifty-fifth of an acre in area. The alleys between these plats have been 19.2 inches in width. By the use of plats and alleys of these dimensions it was possible to sow five plats within the area formerly occupied by a tenth-acre plat. As the plants draw considerable moisture and plant food from the alleys, it has been thought fair to consider these $\frac{1}{55}$ -acre plats as fiftieth-acre plats in computing acre yields.

REPLICATION OF PLATS.

In 1908, 1909, and 1910, when the experiments were conducted on tenth-acre plats, there was only a single plat of each variety. Check

plats of standard varieties of each cereal were sown at regular intervals in 1909 and 1910, and in most of the experiments in 1908. As this method did not appear to be entirely satisfactory, a change was made in 1911 in some of the experiments and in all those conducted from 1912 to 1919. The size of the plats was reduced, as stated in the preceding paragraph, and the experiments were replicated. In the varietal experiments, three to five plats of each variety were grown. In rate-of-seeding and date-of-seeding experiments it has been considered sufficient to grow three plats of each rate or date, as there is a correlation between the different parts of the experiment which is not found in the varietal experiments. Some of the date-of-seeding experiments were sown only in duplicate.

RATES AND DATES OF SEEDING.

The usual rates of seeding of the grains in the varietal and date-of-seeding experiments on both dry and irrigated land are shown in Table VI.

TABLE VI.—*Rates of seeding of the grains in varietal and date-of-seeding experiments on dry and on irrigated land on the Belle Fourche Experiment Farm.*

Crop.	Rate of seeding per acre.		Crop.	Rate of seeding per acre.	
	Dry land.	Irrigated land.		Dry land.	Irrigated land.
Winter wheat.....pecks..	3	4	Barley.....pecks..	5	6
Spring wheat.....do.....	4	5	Flax.....pounds..	22.5	30
Winter rye.....do.....	4	5	Eroso.....do.....	22.5	30
Oats.....do.....	6	10			

Spring grains have been sown as early as seemed practicable. During wet spring weather the seeding has sometimes been considerably delayed. In a few seasons some of the grains have been sown in March, but usually the spring grains were sown between April 1 and May 10. Winter grains were usually sown between September 15 and October 1, which appeared to be the most favorable time for fall sowing.

NURSERY EXPERIMENTS.

NATURE OF THE WORK.

The nursery experiments at Newell have included varieties newly introduced, those of which there was not sufficient seed for sowing in the field plats, and also pure-line selections from the better commercial

varieties. The last has been the most important feature of the nursery work.

The chief objects sought in the pure-line selections were: (1) To obtain high-yielding and drought-resistant strains of wheat, oats, and barley; (2) to obtain a more winter-hardy and high-yielding winter wheat; and (3) to obtain a high-yielding awnless variety of hard red winter wheat.

NURSERY METHODS.

Single heads were selected from the field plats, the aim being to obtain as many types as possible. Each head was described carefully before it was thrashed. The seeds from each head were sown in a 5-foot row, 25 seeds usually being sown in each row. The dates of sowing, emergence, heading, and ripening were recorded, as were such other notes on hardiness, yield, etc., as appeared desirable. Most of the selections were retained and sown in longer rows in the following years. From 1910 to 1915, inclusive, most of the nursery rows were 60 feet long. These rows were sown with the grain drill. Since 1915 most of the nursery experiments were conducted in 16-foot or 17-foot rows, although some of the best strains were tested in 60-foot rows, making possible a more rapid increase of seed. In most cases the nursery experiments were replicated from two to four or occasionally six times, depending on the supply of seed and the area of land available. Yields of grain and straw were recorded, and when the yield of grain was sufficient the weight per bushel also was determined. The better strains and varieties grown in the nursery were later sown in the field plats.

A number of pure-line selections of wheat and oats made at Newell have been tested in field plats for two to seven years.

EXPERIMENTS ON DRY LAND.

EXPERIMENTS WITH WHEAT.

The experiments with wheat at Newell on dry land have included plat and nursery experiments with both spring and winter varieties. These were chiefly varietal, rate-of-seeding, and date-of-seeding experiments, although considerable effort was devoted to the improvement of varieties by selection. Wheat is the most important small-grain crop in the northern Great Plains. Consequently, the experiments with wheat at Newell have been much more extensive than with any other grain.

TABLE VII.—Yields of the varieties of spring wheat grown on dry land on the Belle Fourche Experiment Farm, 1908 to 1919, inclusive.

Class, group, and variety.	C. I. No. ^a	Yields per acre (bushels).														Average.		
		1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1908 to 1919	1913 to 1919	1917 to 1919		
COMMON.																		
Fife:																		
Marquis.....	b 3641					3.8	16.8	8.0	50.9	8.1	8.3	29.3	6.7		18.3	14.8		
Ghirka Spring.....	1517	16.2	11.7	12.9	0	1.9	16.3	40.2	8.9	11.1								
Glyndon.....	2873					0	15.8	6.3	39.8	4.1	9.1							
Kitchener.....	4800											c 30.9	8.5					
Power.....	d 3697	18.5	17.3	10.6	0	0	16.6	5.1	43.4	6.5	10.2	30.0	6.3	13.7	16.9	15.5		
Ruby.....	6047												6.9					
Rysting.....	3022	19.3	15.0	10.3	0	0	15.0	5.1	40.6	4.4	8.8							
Bluestem:																		
Haynes.....	2874					0	14.2	4.7	42.0	5.6	8.0	26.9	5.0	e 12.3	15.2	13.3		
Do.....	3020	18.3	13.8	9.0	0	0	14.1	5.1										
Do.....	3021	17.0																
Preston:																		
Preston.....	3081					0	19.5	7.2	46.9	5.8	8.5	22.7	5.3		16.6	12.2		
Do.....	3087					0	19.0	6.6	47.2									
Pioneer.....	4324							45.4	6.2	9.2	24.0	5.2				12.8		
Ladoga:																		
Changli.....	2911					11.7	14.6	12.2	43.8	8.0	14.4							
Huron.....	4935								5.2	6.6	32.7	5.0				14.8		
Ladoga (Spring Turkey).....	4154					0	16.2	7.9	32.8									
Laramie.....	6235												7.7					
Manchuria.....	f 2492	16.2	16.0	12.8	0	4.5	17.1	7.8	45.6	12.9	12.2	24.2	6.9	14.7	18.1	14.4		
Norka.....	4377												7.5					
Miscellaneous:																		
Prelude.....	4323							35.4	8.1	12.6	27.7	3.1				14.5		
Regenerated Defiance.....	3703							6.6										
DURUM.																		
Kubanka:																		
Acme.....	5284										10.9	35.3	9.7			18.6		
Adjini.....	2941	18.3																
Arnautka.....	1493	22.3	22.6	8.3	0	0	17.1	9.5	54.9	14.8	11.0	34.0	9.4	17.0	21.5	18.1		
Do.....	1537			11.5	0	0												
Do.....	1547	21.3	22.0	9.2	0	0												
Do.....	4064							56.2	10.3	13.1	34.2	9.9				19.1		
Buford.....	5295												8.3					
Kubanka.....	1354	24.8	19.5	4.0	0	0												
Do.....	1440	24.9	21.4	7.4	0	0	15.6		54.4	13.8	11.3	34.5	8.7			18.2		
Do.....	1516	23.8	22.6	5.3	0	0	19.1	9.6	54.5	19.7	11.8	34.9	8.9	17.5	22.6	18.5		
Do.....	2246	21.0			0	0												
Do.....	2882	23.2																
Kubanka No. 8.....	4063								11.0	6.6								
Kubanka Selection No. 712.....	1516										e 12.5	35.8	8.6			19.0		
Kubanka Selection No. 715.....	1516										e 12.5	33.5	9.0			18.3		
Mindum.....	5296												9.0					
Monad.....	3320										11.6	33.6	9.7			18.3		
Pererodka.....	1350	22.5	23.2	5.2	0	0	16.7	9.8	58.2	13.7								
Pierson.....	4163											36.3	6.3					
Yellow Gharnovka.....	1444	22.7	20.9	5.0	0	0	16.5	7.4	54.0									
Peliss:																		
Peliss.....	1584	21.7																
Red Durum:																		
D-5.....	3322										11.8	32.9	8.6			17.8		
Selection No. 735.....	1516										e 10.4	35.3	8.6			18.1		

^a Cereal Investigations number.^b Marquis, C. I. No. 3276, grown 1912 to 1916, inclusive.^c One plat only.^d Power, C. I. No. 3025, grown 1908 to 1916, inclusive.^e Average of Haynes, C. I. No. 3020, from 1908 to 1911, inclusive, and C. I. No. 2874, from 1912 to 1919, inclusive.^f Manchuria Selection No. 2492-38, grown in 1918 and 1919.

SPRING WHEAT.

VARIETAL EXPERIMENTS.

The varieties of spring wheat grown in the plat experiments on dry land are mostly those included in two main classes, the durum wheats and the common hard red spring wheats.⁸ Other types of spring wheat were poorly adapted and were grown only in nursery rows or in preliminary plat experiments. A total of 44 varieties was grown in plats during the 12-year period. In some cases several lots of wheat under the same name but from different sources or different introductions have been included, so that the actual number of distinct varieties is somewhat less than 44. The annual and average yields for all varieties and strains are shown in Table VII.

As shown in Table VII, good yields of spring wheat were produced in 1908, 1909, 1915, and 1918, fair yields in 1913, poor yields in 1910, 1914, 1916, 1917, and 1919, and failures of practically all varieties in 1911 and 1912. These yields depended largely upon the



FIG. 4.—Heads and glumes of two important varieties of spring wheat grown on the Belle Fourche Experiment Farm: 1, Marquis common wheat; 2, Kubanka durum wheat.

⁸ For a more complete discussion of the history and growing of these varieties of wheat, see Clark, J. Allen, Martin, John H., and Smith, Ralph W. Varietal experiments with spring wheat on the northern Great Plains. U. S. Dept. Agr. Bul. 878, 47 p., 3 pl., 2 fig. 1920.

amounts and distribution of the seasonal precipitation. The yields of the durum wheats were considerably reduced in 1910, on account of hot winds at flowering time which prevented fertilization. In 1911 the wheat sown in the spring did not emerge until August. The failure in 1912 was caused by a deficient supply of soil moisture in the spring, together with the low precipitation during May and June. In 1916 the wheat was badly injured by rust.

The durum varieties have outyielded the common varieties in nearly all seasons. This was due only in part to the greater resistance of durum wheat to rust and drought, for the durum varieties have given the highest yields in the most favorable seasons. The Kubanka variety, C. I. No. 1516, has the highest average yield during the en-

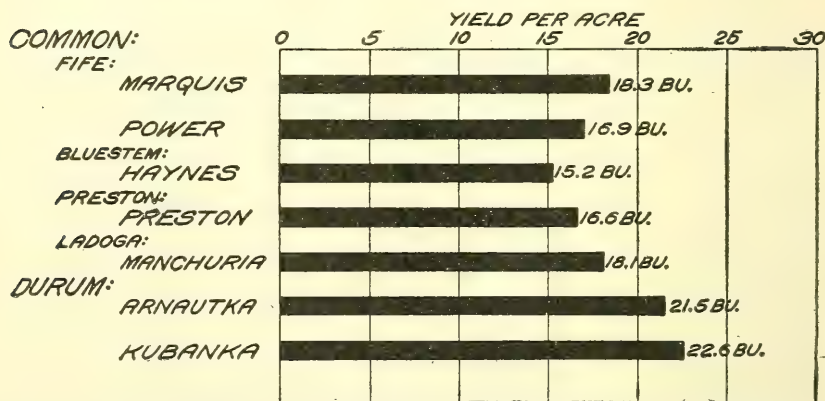


FIG. 5.—Diagram showing the average yields, in bushels per acre, of seven varieties of spring wheat on dry land at the Belle Fourche Experiment Farm during the 7-year period from 1913 to 1919, inclusive.

tire 12 years and also during the 7-year period, 1913 to 1919, inclusive. This variety appears to be slightly more productive than the Kubanka strain, C. I. No. 1440, and is slightly different in appearance. A head of Kubanka wheat is shown in figure 4.

Several other durum wheat varieties yielded about as much as or even more than Kubanka during the three years 1917, 1918, and 1919. These small differences probably are not significant.

Marquis is the highest yielding variety of common wheat. During the period from 1913 to 1919, inclusive, it outyielded all other common-wheat varieties. A head of Marquis wheat is shown in figure 4. Manchuria, the second highest yielding common wheat, is a soft wheat of low milling and baking value. The Power, Haynes, and Preston varieties show average yields since 1913 considerably below that of Marquis. The yields of the leading varieties grown since 1913 are shown graphically in figure 5,

Only five varieties were grown during the entire 12-year period. Of these only two, Arnautka, C. I. No. 1493, and Kubanka, C. I. No. 1516, were grown continuously from the same original strain. In order to have the experiments coordinated with other experiments with wheat in the northern Great Plains, seed of Power and Haynes wheat having different C. I. numbers than those previously grown was used in the later years. In 1918 and 1919 a selection of Manchuria was substituted for the parent variety in the experiments. Table VIII shows the average dates of heading and ripening, the average height, the average percentage of stem-rust infection, the average weight per bushel, and the average yields of grain and straw of the five varieties of spring wheat grown during each of the 12 years from 1908 to 1919, inclusive.

The durum varieties shown have higher yields of grain and straw, a heavier weight per bushel, and a lower stem-rust infection. The Manchuria variety is considerably earlier and the Haynes much later than the other varieties shown.

TABLE VIII.—*Agronomic data for five varieties of spring wheat grown on dry land on the Belle Fourche Experiment Farm, 1908 to 1919, inclusive.*

Group and variety.	C. I. No.	Date of—		Height. ^a	Stem rust. ^b	Weight per bushel. ^c	Yields per acre.	
		Head- ing. ^a	Matu- rity. ^a				Grain.	Straw. ^a
Fife:				<i>Inches.</i>	<i>Per cent.</i>	<i>Pounds.</i>	<i>Bushels.</i>	<i>Pounds.</i>
Power.....	c 3697	July 8 d	July 31	28	35.0	57.3	13.7	1,837
Bluestem:								
Haynes.....	e 2874	July 11 d	Aug. 2	29	42.5	53.7	12.3	1,815
Ladoga:								
Manchuria.....	2492	July 1	July 27	31	24.0	56.0	14.7	1,699
Durum:								
Arnautka.....	1493	July 4	July 30	33	10.5	59.8	17.0	1,877
Kubanka.....	1516	July 5	...do....	30	7.0	60.3	17.5	1,930

^a Average for 9 years (1908 to 1910, 1913 to 1917, and 1919).

^b Average for 2 years (1915 and 1916).

^c Power, C. I. No. 3025, grown from 1908 to 1916, inclusive.

^d Date of heading computed in 1914.

^e Haynes, C. I. No. 3020, grown from 1908 to 1912, inclusive.

RATE-OF-SEEDING EXPERIMENTS.

A rate-of-seeding experiment with Kubanka durum wheat, C. I. No. 1440, was conducted during the 9-year period 1909 to 1917, inclusive. The wheat was not sown in 1911, and the crop failed in 1912 on account of drought. The yields were too low to be of much significance in 1910 and 1914. In 1915 the yields were exceedingly large. The experiment was conducted on single tenth-acre plats in 1909 and 1910, but in triplicate fiftieth-acre plats in all other years.

The rates of seeding ranged by 1-peck intervals from 2 to 8 pecks per acre, but the wheat was not sown at all of these rates during all years of the experiment. The annual and average yields obtained in the rate-of-seeding experiment are shown in Table IX.

TABLE IX.—Yields of *Kubanka durum* spring wheat grown in rate-of-seeding experiments on dry land on the Belle Fourche Experiment Farm in 1909, 1910, and 1913 to 1917, inclusive.

Rate of seeding per acre.	Yields per acre (bushels).								
	1909	1910	1913	1914	1915	1916	1917	Average.	
								1909 to 1917	1913 to 1917
2 pecks.....	12.5	5.5							
3 pecks.....			9.3	2.2	61.6	11.2	12.4		19.3
4 pecks.....	14.4	5.5	9.8	2.0	60.1	10.7	12.4	16.4	19.0
5 pecks.....	16.8	2.8	10.4	2.3	61.4	11.2	11.6	16.6	19.4
6 pecks.....	17.2	1.8	9.9	2.0	59.2	10.9	12.3	16.2	18.9
7 pecks.....			10.3	2.0	57.4	11.5	12.4		18.7
8 pecks.....	17.9	3.4	10.6	1.9					

Several interesting facts are brought out by the data shown in Table IX: (1) The net yields were not increased by sowing at a rate in excess of 3 pecks per acre; (2) thin seeding will not materially increase the yields nor prevent failure in dry seasons; and (3) thick seeding reduced the yields only slightly below those of the medium and thin seedings.

It has commonly been assumed that durum wheat should be sown at the rate of 4 to 5 pecks per acre on dry land, as compared with 3 pecks of common wheat, because of the large size of the durum kernels and also because durum wheat tillers less freely than common wheat. Apparently this is offset by other characters of durum wheat, such as the large size of spikes and kernels produced. The above experiment was always conducted on well-prepared land. On a rough seed bed a higher rate of seeding than 3 pecks per acre might be necessary. The slight differences in yield shown above from the different rates of seeding are not significant.

In Table X are shown the average number of days from emergence to maturity, the average height, weight per bushel, and yields of grain and straw of the wheat sown at each rate during the period from 1913 to 1917, inclusive. The average stands recorded during the years 1915 to 1917, inclusive, in thousands of plants per acre, also are shown.

The proportion of straw to grain was slightly higher in the plats sown at the higher rates. The plats sown at 3 pecks per acre matured about one day later than the others. In most years it was observed that the plats sown at the higher rates matured first, but this was not true in all seasons. The wheat from the plats sown at 6 and 7 pecks per acre was an inch shorter than that on the other plats. The weight per bushel of the grain from the thicker sown plats is slightly less than from the plats sown at 3 to 4 pecks per acre.

TABLE X.—Average agronomic data for *Kubanka durum* spring wheat grown in rate-of-seeding experiments on dry land on the Belle Fourche Experiment Farm, 1913 to 1917, inclusive.

Rate of seeding, per acre.	Emer- gence to maturity.	Height.	Weight per bushel.	Stand per acre. ^a	Yields per acre.	
					Grain.	Straw.
	<i>Days.</i>	<i>Inches.</i>	<i>Pounds.</i>	<i>Plants.</i>	<i>Pounds.</i>	<i>Pounds.</i>
3 pecks.....	94	30	58.6	382,000	1,158	2,458
4 pecks.....	93	30	58.7	428,000	1,140	2,421
5 pecks.....	93	30	58.3	517,000	1,164	2,649
6 pecks.....	93	29	58.3	604,000	1,134	2,500
7 pecks.....	93	29	58.2	678,000	1,122	2,479

^a Average for 3 years, 1915, 1916, and 1917.

DATE-OF-SEEDING EXPERIMENTS.

A date-of-seeding experiment with *Kubanka* spring wheat was conducted in 1912, 1915, and 1916. In 1912 the crop was a failure except on the late-sown plats, because of drought during June. In 1915 and 1916 the yields from the early sowing were highest, with the later sowings yielding considerably less. The yield from the earliest sowing in 1916 is not shown, because the wheat was sown on land where soil blowing was unusually severe. The yields from the date-of-seeding experiment are shown in Table XI.

TABLE XI.—Yields of *Kubanka durum* spring wheat grown in date-of-seeding experiments on dry land on the Belle Fourche Experiment Farm in 1912, 1915, and 1916.

Date sown.	Yields per acre (bushels).			
	1912	1915	1916	Average.
April 9 to 25.....	0	52.5	14.2	22.2
May 1 to 8.....	0	37.2	12.3	16.5
May 15 to 26.....	13.5	27.3	4.9	15.2

As shown in Table XI, the early-sown wheat yielded an average of 22.2 bushels per acre, the plats from the second sowing yielded 16.5 bushels, while those sown last yielded only 15.2 bushels per acre. This was in accordance with the usual experience with spring wheat, oats, and barley at Newell, viz, the earlier the sowing the higher the yield.

NURSERY EXPERIMENTS.

Many varieties of spring wheat were grown in rows, but because of their apparent lack of adaptability were not sown in plats. A considerable number of foreign varieties were thus tested in a preliminary way and later discarded. Most of the nursery experiments with spring wheat consisted in the testing of pure-line selections made at Newell from both durum and common spring wheats. Selec-

tions from the Kubanka variety appeared to be most promising. Three of these, designated as Nos. 1440-735, 1516-712, and 1516-715, gave the highest average yields and were grown in plats in the varietal experiments during 1917, 1918, and 1919. The yields in the plat experiments, as shown in Table VII, were not higher than other durum varieties, however, so that nothing of value was obtained from the nursery experiments with spring wheats. A selection of the Manchuria variety, designated as No. 2492-38, proved to be a high-yielding strain in dry seasons. In 1918 and 1919 it was substituted for the parent bulk Manchuria in the varietal experiments in plats. Because this selection is inferior in both yield and quality to several other varieties, it is not considered to be of any particular value.

WINTER WHEAT.

Experiments with winter wheat on dry land have included tests of varieties and selections and of rates and dates of seeding. A large part of the nursery work also was devoted to the improvement of winter wheat by selection. Preliminary experiments showed definitely that the only varieties of winter wheat adapted to the conditions at Newell belonged to the hard red winter or Crimean group. The varieties grown in plats, therefore, consisted almost entirely of wheats of this type.

VARIETAL EXPERIMENTS.

The varietal experiments with winter wheat were begun in the fall of 1907 and continued until 1917. The 1918 crop was completely winterkilled, and no wheat was sown in the fall of 1918. Good yields were obtained in 1908, 1909, 1913, 1914, and 1915. The yields for the latter year were extremely large. The yields in 1910 and 1917 were reduced by drought and in 1916 by winterkilling, rust, and drought. The crop of 1911 was completely killed by drought, and the wheat sown in the fall of 1911 did not emerge until late the following spring, so that no crop was obtained in 1912. The wheat was sown on summer-fallowed land each year and since 1912 has been grown in plats replicated three or five times. The yields are shown in Table XII.

The varieties grown are all of the Crimean group except Alton (Ghirka Winter), an awnless hard red winter variety, and Fultz, a soft red winter wheat. Some differences in yields were obtained from several lots of the Crimean wheats, but it is not certain that these differences are significant. The five varieties which were grown each year from 1910 to 1917, inclusive, gave exactly the same average yield, 21.5 bushels per acre.

TABLE XII.—Yields of the winter-wheat varieties grown on dry land, on the Belle Fourche Experiment Farm, 1908 to 1917, inclusive.

Group and variety.	C. I. No.	Yields per acre (bushels).										Average.	
		1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1908-1917	1910-1917
Crimean:													
Alberta Red.....	2979			16.7	0	0	35.0		64.2	11.6			
Beloglina.....	1667			19.2	0	0	37.2	29.9	63.8	11.7	10.3		21.5
Do.....	2239			19.2	0	0	39.4	29.3	59.4	7.8			
Crimean.....	1435	18.7	31.5	19.7									
Do.....	1437	25.3	36.0	20.3	0	0	36.4						
Kharkof.....	1442	25.4	40.3	22.7	0	0	38.6	28.7	63.8	14.2	4.7	23.8	21.5
Do.....	1583	22.5	39.0	23.6	0	0	38.8	29.1	62.6	13.2	4.7	23.3	21.5
Do.....	2208			17.5									
Do.....	4207									9.8			
Theiss.....	1561			19.4	0	0	36.8	31.6	66.3	12.3	6.4		21.5
Turkey.....	1558	24.1	41.0	17.8	0	0	38.1		65.0	10.3	5.1		
Do.....	1571	25.5	39.0	20.3	0	0	38.7	29.6	65.0	12.3	6.0	23.5	21.5
Do.....	2943			15.0	0	0	39.3		60.1	9.1			
Do.....	2998			14.2									
Do.....	3055	22.3	44.5	(a)	0	0	35.0	29.6	64.1	9.6	7.9	21.2	
Alton:													
Alton.....	1438								53.7	11.1	6.5		
Soft winter:													
Fultz.....									37.2				

^a Did not emerge.

In Table XIII are shown the average dates of heading and maturity, weight per bushel, and yields of grain and straw of two strains of Kharkof and one of Turkey wheat grown on the Belle Fourche Experiment Farm from 1908 to 1917, inclusive. The yields also are shown graphically in figure 6. It is seen that the dates of heading

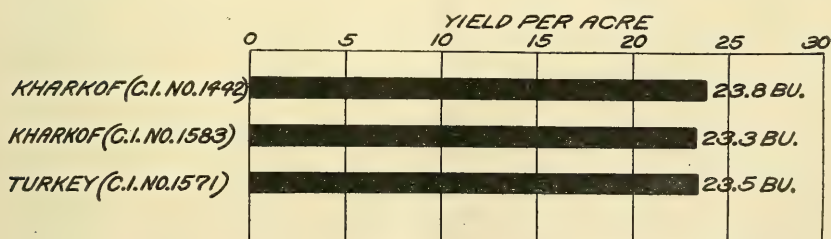


FIG. 6.—Diagram showing the average yields, in bushels per acre, of the leading varieties of winter wheat on dry land at the Belle Fourche Experiment Farm for the 12-year period from 1908 to 1919, inclusive.

and maturity and the height are the same for all three wheats and that the differences in weight per bushel and yield are too small to be significant. From the results obtained it is concluded that the bulk unselected varieties, Turkey and Kharkof, are identical in all the above characters, including yield. These varieties, however, have outyielded all others grown in the plat and nursery experiments.

TABLE XIII.—Average agronomic data for three varieties of winter wheat grown on dry land on the Belle Fourche Experiment Farm, 1908 to 1917, inclusive.

Variety.	C. I. No.	Date of —		Height. ^b	Weight per bushel.	Yields per acre. ^c	
		Head-ing. ^a	Matur-ity. ^a			Grain.	Straw.
Kharkof.....	1442	June 29	July 25	33	59.5	23.8	2,319
Do.....	1583	do..	do..	33	59.1	23.3	2,340
Turkey.....	1571	do..	do..	33	59.3	23.5	2,347

^a Average for 6 years, 1910 and 1913 to 1917, inclusive.^b Average for 8 years, 1908 to 1910 and 1913 to 1917, inclusive.^c Average for 10 years, 1908 to 1917, inclusive.

EXPERIMENTS WITH WINTER-WHEAT SELECTIONS.

About 600 selected heads of Turkey, Kharkof, and Crimean wheats were sown in head rows in the fall of 1908. Practically all of these were sown in 60-foot rows the following year and many of them for several years following. The selections giving the highest yields in the nursery were later grown in plats. About 35 of these selections were sown in plats in the fall of 1910, but they failed on account of drought. A few selections were again sown in plats in the fall of 1912 and these produced a crop in 1913.

Several additional selections which had shown high yields in the nursery experiments were sown in plats in the fall of 1914. The better strains were continued in the plats in 1916 and a few in 1917. The 1918 crop was entirely winterkilled. The yields are shown in Table XIV.

TABLE XIV.—Yields of the winter-wheat selections compared with the unselected parent varieties grown on dry land on the Belle Fourche Experiment Farm, 1913 to 1917, inclusive.

Group and variety	C. I. No.	Yields per acre (bushels).					
		1913	1914	1915	1916	1917	Average.
Crimean:							
Kharkof.....	1442		28.7	53.0	13.4	4.7	.....
Do.....	4207	17.9	28.6	51.6			.....
Turkey.....	3055	20.7	29.6	53.3	12.4	7.9	24.8
Turkey selection 159.....		24.2	27.1	55.4	15.3	8.9	26.1
Turkey selection 173.....				57.7	14.1		.....
Turkey selection 209.....				42.7			.....
Turkey selection 285.....				47.0	12.3		.....
Turkey selection 296.....		21.4	27.3	52.0	13.3	7.3	24.2
Crimean selection 378.....		17.7	26.2	47.0	13.3		.....
Crimean selection 379.....		16.9					.....
Alton (awnless):							
Alton selection 343.....	5298		30.8	46.6	11.9	7.1	.....
Alton selection 350.....				43.9	9.1		.....
Alton selection 352.....	5299	15.6	31.2	49.8	12.1	6.8	23.1
Newton (Alton selection 367).....	5300	16.9	31.8	49.4	10.5	4.8	22.7

Four selections were grown during each of the five years, and seven others were grown from one to four years each. Turkey, C. I. No.

3055, was grown each year, and Kharkof, C. I. No. 1442, was grown from 1914 to 1917, inclusive, for comparison. Four of these selections are awnless, very similar to Alton (Ghirka Winter) wheat. They, however, are more vigorous and have larger kernels than Alton. The grain is very similar to that of Turkey and probably equal to that variety in quality.

Selection No. 159 produced the highest average yield, 26.1 bushels per acre, which was 1.3 bushels more than the parent strain, C. I. No. 3055. This selection was one of the highest yielders in the nursery experiments, and it also outyielded all varieties and selections in the experiments under irrigation. Of the 600 original selections this is the only one which has shown a marked increase over the parent varieties.

The awnless strains yielded less than Turkey or Kharkof and most of the awned selections. The highest yielding awnless selection, C. I. No. 5299, has an average yield of 1.7 bushels per acre less than Turkey, but it yielded slightly more than the Turkey variety in 1914. The better awnless selections have been fully as hardy and nearly as resistant to drought as the Turkey variety. Because of the lower yields of the awnless strains none of them was distributed.

RATE-OF-SEEDING EXPERIMENTS.

Experiments to determine the best rate to sow Kharkof winter wheat were attempted from 1910 to 1918, inclusive. The 1910 crop failed to germinate, and the 1912 crop did not emerge until late in the spring following the seeding and was plowed up. The 1911 crop was killed by spring and summer drought and the 1917 and 1918 crops were destroyed by a combination of winterkilling and soil blowing. Results from the rate-of-seeding experiment were thus obtained only during the period from 1913 to 1916, inclusive. Good crops were obtained except in 1916, when winterkilling and soil blowing injured the crop, in addition to severe damage from stem rust. The rates of seeding here recorded ranged from 2 to 7 pecks per acre. The yields are shown in Table XV.

TABLE XV.—*Yields of Kharkof winter wheat grown in rate-of-seeding experiments on dry land on the Belle Fourche Experiment Farm, 1913 to 1916, inclusive.*

Rate of seeding, per acre.	Yields per acre (bushels).				
	1913	1914	1915	1916	Average.
2 pecks.....	26.4	23.0	36.7	3.1	22.3
3 pecks.....	28.0	26.6	42.6	4.0	25.3
4 pecks.....	27.3	24.9	48.3	4.6	26.2
5 pecks.....	26.8	27.4	43.6	5.1	25.7
6 pecks.....	27.4	24.6	45.8	5.4	25.8
7 pecks.....	28.2	27.8	44.0	6.3	26.5

The yields from all rates of seeding from 3 to 7 pecks per acre are nearly the same. The yields from the 2-peck seedings, however, have been the lowest each year. In 1913, 1914, and 1916, the 7-peck seeding gave the highest yield, while in 1915 the highest yield per acre was obtained from the 4-peck seeding. The 7-peck seeding gave the highest average yield per acre during the 4-year period, but the largest net yield was obtained from seeding at the rate of 4 pecks per acre. Sufficient data have not been obtained to draw definite conclusions, but apparently 4 pecks per acre is the most profitable rate of seeding.

DATE-OF-SEEDING EXPERIMENTS.

A date-of-seeding experiment with Turkey winter wheat was conducted each year from 1908 to 1918, inclusive. Drought destroyed the crops of 1911 and 1912, and the wheat was almost entirely destroyed by winterkilling and soil blowing in 1916, 1917, and 1918. Some injury from soil blowing resulted in most other years of the experiment. The soil blowing usually occurred in early spring before the rains had begun and before the wheat had made much, if any, growth. The yields from the date-of-seeding experiment with winter wheat during the years in which yields were obtained are shown in Table XVI.

TABLE XVI.—Yields of Turkey winter wheat grown in date-of-seeding experiments on dry land on the Belle Fourche Experiment Farm, 1908 to 1910 and 1913 to 1915, inclusive.

Date of seeding.	Yields per acre (bushels).						Average. ^a
	1908	1909	1910	1913	1914	1915	
August 1.....				29.2			
August 16.....		37.5	19.3	28.1			
September 1.....	23.0	39.0	8.3	28.1			
September 16.....	20.3	40.5	22.0	^b 28.1	^c 20.2	61.6	34.1
October 1.....	24.3	43.0	(^d)	28.1	21.1	60.9	35.5
October 16.....	24.7	42.0	13.3	21.4	20.7	56.5	33.1
November 1.....	25.5	37.3	13.2	16.3	19.1	55.2	30.7
November 16.....				16.1		51.9	

^a Yields for 1910 omitted because of irregularities.

^b Not sown, yield assumed from earlier and later sowings.

^c Sown September 20.

^d Did not germinate.

In 1908 the latest date of seeding, November 1, produced the highest yield. In 1909 the October 1 seeding yielded the highest. The results in 1910 were very irregular, owing to poor germination and soil blowing on some of the plats. In 1913 the August 1 seeding gave the highest yield. A seeding was not made the previous fall on September 16, but as the yields from the seedings of August 16, September 1, and October 1 were all 28.1 bushels, the yield for this date was assumed to be the same, in order to determine the average

yield for five years. The October 1 seeding gave the highest yield in 1914 and the September 16 seeding in 1915.

In the column of Table XVI showing the average yields, the results for 1910 are omitted because of the large irregularities previously mentioned. The highest average yield per acre was obtained from the October 1 seeding and the next highest from the September 16 seeding. With the exception of 1908, seeding later than October 1 resulted in decreased yields each year.

Only limited data are available, but apparently there is no advantage in seeding wheat earlier than September 16 at Newell. In 1916 and 1917 the wheat in the date-of-seeding experiment was so badly injured by soil blowing and winterkilling that it was disked up. It was observed, however, that the plats sown late showed the highest winter survival, the earliest sown wheat having the lowest survival. In both of these years the wheat in the November 1 seeding did not emerge and apparently had not begun to germinate until spring. The wheat in these late-sown plats showed a much better stand in the spring than that in the earlier seedings where the plants had emerged in the fall. In the fall of 1914 the wheat in the November 1 seeding started to germinate, but the plants did not emerge until about April 15 the following spring. The wheat sown November 16 did not even start germination in the fall but it emerged about April 17. The average yield from the three plats sown November 16 was 51.9 bushels per acre.

Winterkilling at Newell is not due to heaving of the plants, but apparently is a result of low temperature, drying out of the soil, and mechanical injury from soil particles blown by the wind. The surviving wheat plants die down to the crown and make no growth during the winter period of nearly five months. It was observed in these experiments that wheat plants which had reached the 2-leaf stage survived the winter as well as or better than plants which had formed several tillers.

NURSERY EXPERIMENTS.

A large part of the nursery work with winter wheat consisted of the testing of the several hundred selections from the Turkey, Kharkof, and Crimean varieties previously mentioned. In 1915, 1916, and 1917 several hundred additional selections of Kharkof were made. Most of these were subsequently destroyed by winterkilling and soil blowing during the three rather severe winters of 1915-16, 1916-17, and 1917-18.

Some hybrids made between awned and awnless types also were destroyed during this time. A large number of winter-wheat varieties were grown in the nursery in 1909 and 1910 and a number each year since then. None of these except the hard red winter varieties

of the Crimean group have given satisfactory yields. The Alton (Ghirka Winter) and Buffum No. 17 varieties were somewhat promising, but were inferior to Turkey in both yield and quality.

COMPARISON OF SPRING AND WINTER WHEATS.

A comparison of the annual and average yields of Kharkof winter wheat with Kubanka durum and Power common spring wheats is shown in Table XVII. The average yields also are shown graphically in figure 7. No winter wheat was sown in the cereal experiments in the fall of 1918, so the yield of winter wheat shown was obtained from a plat of the Turkey variety on fallowed land in the experiments of the Office of Dry-Land Agriculture. The Kubanka and Power varieties were grown in the spring-wheat varietal experiments each year. Kubanka spring wheat, C. I. No. 1440, was sown in the same series with the winter wheat varieties from 1913 to 1917, in-

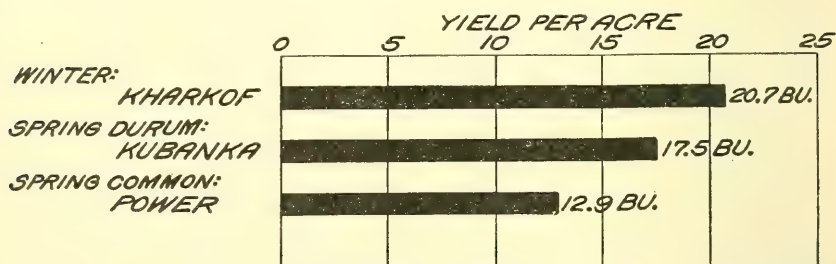


FIG. 7.—Diagram showing the average yields, in bushels per acre, of the best varieties of winter wheat and of durum and common spring wheat on dry land at the Belle Fourche Experiment Farm for the 12-year period from 1908 to 1919, inclusive.

clusive. The average yield during this 5-year period was the same as for Kubanka, C. I. No. 1516, in the spring-wheat varietal experiment, so the yields of the latter are shown here. In 1914 the spring wheat was sown on corn ground instead of fallowed land, so the yields are not entirely comparable with those of winter wheat, which was grown on fallow every year. Plats of Kharkof winter wheat, Kubanka spring wheat, and Swedish winter rye are shown in figure 8.

The crops of both winter and spring wheat in 1911 and 1912 were destroyed by drought. The 1918 crop of winter wheat was destroyed by fall drought, winterkilling, and soil blowing.

Kharkof winter wheat has outyielded Kubanka durum, the highest yielding variety of spring wheat, in 7 out of 10 years in which a crop was obtained. The average yield of Kharkof is 20.7 bushels per acre, compared with 17.5 bushels of Kubanka and 12.9 bushels of Power. The crops of winter wheat in 1916, 1917, and 1918 were damaged by soil blowing and winterkilling, so that spring wheat was more successful during this period. The Kharkof variety was injured by rust in 1916 more than Kubanka, which is rather resistant.

TABLE XVII.—*Yields of the better varieties of winter wheat and of durum and common spring wheats grown on dry land on the Belle Fourche Experiment Farm, 1908 to 1919, inclusive.*

Group and variety.	C. I. No.	Yields per acre (bushels).												Average.
		1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	
Winter:														
Kharkof..	1442	25.4	40.3	22.7	0	0	38.6	28.7	63.8	14.2	4.7	0	^a 10.0	20.7
Springdurum:														
Kubanka..	1516	23.8	22.6	5.3	0	0	19.1	9.6	54.5	19.7	11.8	34.8	8.9	17.5
Spring common:														
Power....	3025	18.5	17.3	10.6	0	0	16.6	5.1	43.4	6.5	10.2	30.0	6.3	12.9

^a Not grown, yield from a single plat on summer fallow in experiments of the Office of Dry-Land Agriculture.

^b Power, C. I. No. 3697, grown from 1916 to 1919, inclusive.

Winter wheat, although giving higher average yields, is somewhat less certain than spring wheat in the vicinity of Newell, owing to poor germination of seed during cold fall weather, greater injury



FIG. 8.—Plats on dry land at the Belle Fourche Experiment Farm in 1917: 1, Kubanka spring wheat; 2, Swedish winter rye; 3, Kharkof winter wheat. Note the differences in stand and growth between the winter rye and the winter wheat due to the greater hardness of the rye.

from soil blowing, and the possibility of winterkilling. In case of failure of winter wheat from these causes, however, there is still an opportunity to sow spring wheat or some other spring crop.

EXPERIMENTS WITH OATS.

Oats is perhaps the most successful feed crop of all the small grains in this region. The yields of oats on the Belle Fourche Experiment Farm, however, usually have been less in pounds per acre than the yields of wheat. Oats are most profitably grown when sown on corn ground early in the spring. If drought or hot winds prevent the oats from filling, the crop can be cut for hay.

VARIETAL EXPERIMENTS.

During the 12-year period from 1908 to 1919, inclusive, 19 varieties and strains of spring oats have been grown in plats. It was soon found that only the early varieties were well adapted to the region, but a few midseason and late varieties were continued in the experiments for comparison. Only three varieties of oats were grown during all of the 12 years. Several early varieties and strains were added to the experiment in 1910, 1912, and 1916. The annual and average yields of the oat varieties are shown in Table XVIII.

TABLE XVIII.—Yields of oat varieties grown on dry land on the Belle Fourche Experiment Farm, 1908 to 1919, inclusive.

Group and variety.	C. I. No.	Yields per acre (bushels).															Average.		
		1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1908 to 1919	1912 to 1919	1916 to 1919			
Early yellow: ^a																			
Kherson.....	459	47.5	25.7	15.0	0	6.2	21.9	13.8	110.8	40.8	33.8	37.8	4.4	29.7	33.7	29.2			
Sixty-Day.....	165	46.6	25.0	15.6	0	6.6	22.7	113.7	37.4	34.1	39.8	5.5				29.2			
Sixty-Day selection.....	625			14.4	0	7.9	21.6	13.4	107.2										
Do.....	626			16.6	0	9.9	24.6	14.2	117.1	43.4	35.9	39.8	4.2		36.1	30.8			
Do.....	165					7.1	23.3	12.2	106.7	41.8	33.8	34.9	4.0		33.0	28.6			
Do.....	566																		
Do.....	165					6.2													
Albion (Iowa No. 103).....	562									35.6	30.6	40.6	3.9			27.7			
Richland (Iowa No. 105).....	729									33.5	30.6	39.3	5.0			27.1			
Seventy-five Day.....	787					7.5	21.0	12.8	102.5										
Nebraska No. 21.....	337																		
Do.....	841												4.4						
Early Red:																			
Burt.....	293					6.0	22.4	16.0	108.0	38.0	37.4	36.4	5.7		33.7	29.4			
Midseason white:																			
Big Four.....	658		32.0	3.6	0	14.1	19.5	0											
Canadian.....	444	38.8	21.3	4.4	0	10.4	18.5	0	92.9										
Danish.....	441	36.1																	
Great Dane.....			26.6																
Swedish Select.....	134	38.1	28.4	2.3	0	9.2	15.2	0	113.7	33.0	19.7	34.6	2.3	24.7	28.5	22.4			
Late white (side):																			
Yellow Giant.....	342	19.4	17.5	0	0														
White Russian.....	551	30.9	20.0	0	0	22.7	14.3	0	106.1	26.8	6.4	46.6	1.7	23.0	28.1	20.4			
White Tartarian.....	300	30.9	22.8	0	0														

^a The Sixty-Day selections, and also Albion and Nebraska No. 21, which are selections from Kherson, have white kernels, while the parent varieties usually have yellow kernels.

Table XVIII shows that good yields of oats were obtained from all early varieties in 1908, 1915, 1916, 1917, and 1918. Fair yields were grown in 1909 and 1913, and poor yields or failures in the other years. In 1909, 1912, and 1918, the midseason and late varieties were somewhat favored by ample moisture late in the season. In years such as 1910, 1914, 1917, and 1919, when the season was very dry, the early varieties yielded better than the later ones. The Kherson variety, C. I. No. 459, gave the highest average yield, 29.7 bushels per acre, during the 12-year period. A panicle and spikelets of Kherson oats are shown in figure 9. The Swedish Select and

White Russian, both later varieties, yielded considerably less. The Sixty-Day selection, C. I. No. 626, has given the highest yields of any of the varieties since it has been included in the experiments. During the eight years from 1912 to 1919, this variety averaged 2.4 bushels per acre more than Kherson. This variety has a white hull, but usually has a low weight per bushel.

The Sixty-Day variety, C. I. No. 165, has been grown in all years except 1914. During this period it has averaged nearly the same as Kherson, with which it is practically identical. The Burt variety, C. I. No. 293, has been continued in the experiments since 1912. The average of Burt was the same as for Kherson. The Burt variety as grown is a mixture of various colors of kernels.

The Sixty-Day selection, No. 165-566, has yielded slightly less than Kherson or the parent variety, Sixty-Day. It has a white kernel of good quality, however. The Richland and Albion varieties have been included in the experiments since 1916, but have not yielded as high as the other early varieties.

Table XIX shows the average data recorded on the dates of heading and maturity, the height, weight per bushel, and the yields of grain and straw for the three varieties of oats which were grown during the entire 12-year period. The average yields of these three varieties are shown graphically in figure 10. The yield differences are largely due to the greater earliness and shorter straw of Kherson. This variety has an average

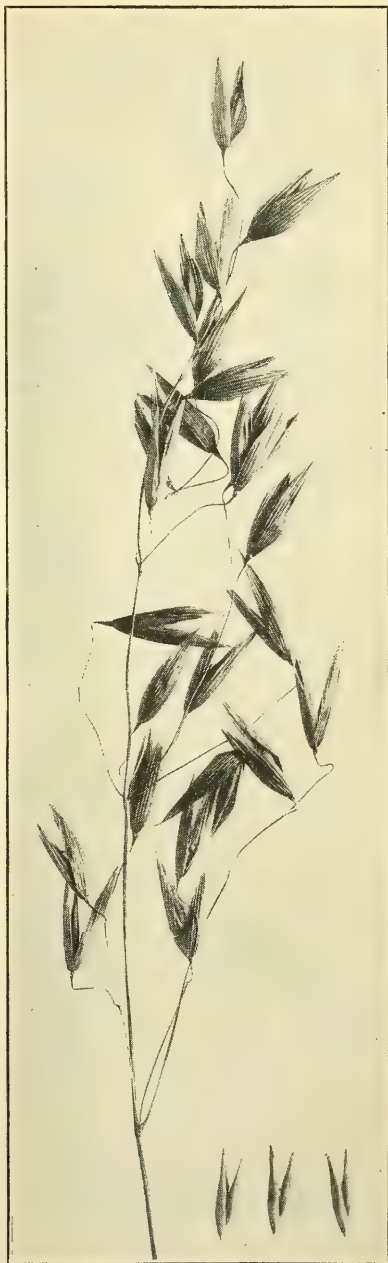


FIG. 9.—Panicle and spikelets of the Kherson oat, the leading dry-land variety at the Belle Fourche Experiment Farm.

maturity 11 days earlier than Swedish Select and 18 days earlier than White Russian. The average height of Kherson was 4 inches less than that of the other two varieties listed. The proportion of grain to straw also is much higher in the Kherson than in the other varieties. The Sixty-Day and other early varieties have given about the same data in the experiments as are shown for Kherson.

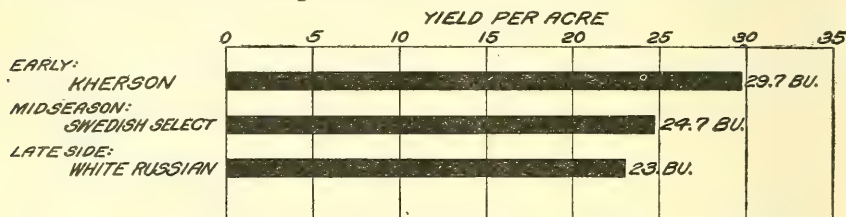


FIG. 10.—Diagram showing the average yields, in bushels per acre, of three varieties of oats on dry land at the Belle Fourche Experiment Farm for the 12-year period from 1908 to 1919, inclusive.

In 1907, two plats of Boswell Winter oats, C. I. No. 480, were sown. Only a small percentage of the plants survived the winter, but these tillered so freely that a yield of 28.5 bushels per acre was obtained. This variety was again sown in 1908 and 1909, but winter-killed entirely each year. Winter oats are not sufficiently hardy for western South Dakota.

TABLE XIX.—Average agronomic data for three varieties of oats grown on dry land on the Belle Fourche Experiment Farm, 1908 to 1919, inclusive.

Variety.	C. I. No.	Date of—		Height. ^a	Weight per bushel. ^a	Yields per acre.	
		Head-ing. ^a	Ripen-ing. ^a			Grain. ^b	Straw. ^c
				Inches.	Pounds.	Bushels.	Pounds.
Kherson.....	459	July 2	July 23	24	30.4	29.7	1,131
Swedish Select.....	134	July 11	Aug. 3	28	29.8	24.7	1,330
White Russian.....	551	July 19	Aug. 10	28	31.3	23.0	1,492

^a Average for 9 years (1908 to 1910, 1912, 1913, 1915 to 1917, and 1919).

^b Average for 12 years, 1908 to 1919, inclusive.

^c Average for 10 years, 1908 to 1913, 1915 to 1917, and 1919.

NURSERY EXPERIMENTS.

The growing of head selections of oats was begun on the Belle Fourche Experiment Farm in 1908, from selections made at the Highmore (S. Dak.) substation in 1907. Other selections were added later, so that a considerable number have been tested. The two most promising selections made at Highmore were included in the plat experiments at Newell in 1912, one of which, No. 165-566, has been continued in the plats each year. As the average yield of this strain is slightly less than that of the parent variety, it is apparent that nothing was accomplished in the improvement of oats by selection.

Many varieties also were grown in nursery rows. Of these, an unnamed variety, designated as C. I. No. 357, outyielded all other varieties and strains during a period of several years. This variety was being increased for plat experiments in 1918, but was never grown in plats at Newell.

RATE-OF-SEEDING EXPERIMENTS.

A rate-of-seeding experiment with oats was conducted on dry land during six seasons. Good yields were obtained in all years except 1910 and 1912. These rates of seeding varied by 2-peck intervals from 2 to 12 pecks per acre, but only four different rates were sown during all of the years. The varieties used in the experiment were Kherson, C. I. No. 459, in 1909 and 1910; Sixty-Day, C. I. No. 165, in 1912 and 1913; and Sixty-Day selection, No. 165-566, in 1915 and 1916. As these varieties are of very similar character, the data are practically as uniform as if the same variety had been grown throughout the entire experiment. The yields are shown in Table XX.

The highest average yields were obtained from sowing the oats at the rate of 6 pecks per acre, with a gradual decrease if sown at higher or lower rates of seeding. The results were so strikingly in favor of the 6-peck rate that the experiment was discontinued in 1916.

TABLE XX.—Yields obtained in rate-of-seeding experiments with oat varieties ^a on dry land on the Belle Fourche Experiment Farm, 1909 to 1916, inclusive.

Rate of seeding per acre.	Yields per acre (bushels).						
	1909	1910	1912	1913	1915	1916	Average.
2 pecks.....	25.9						
4 pecks.....	30.2	11.9	8.9	28.2	120.0	40.0	39.8
6 pecks.....	32.8	12.5	10.3	27.3	118.2	42.5	40.6
8 pecks.....	35.3	10.3	9.2	27.3	104.8	40.6	37.9
10 pecks.....	35.9	4.1	9.7	28.1	109.6	36.1	37.2
12 pecks.....		3.4	9.1	28.2			

^a Kherson, C. I. No. 459, grown in 1909 and 1910; Sixty-Day, C. I. No. 165, in 1912 and 1913; and Sixty-Day selection, 165-566, in 1915 and 1916.

Table XXI shows the average number of days from emergence to maturity, the height, weight per bushel, stand of plants per acre, and yields in pounds per acre of grain and straw of the oats in the rate-of-seeding experiments. The data are shown for only four rates of seeding, viz, 4, 6, 8, and 10 pecks per acre. The period of maturity and the height of the plants decrease with the increase in the rate of seeding. The weights per bushel are slightly higher from the heavier rates of seeding. The number of plants per acre is not quite proportional to the rate of seeding. This is due largely to the error in counting the plants in the thicker seedings where the

plants are too close together to be separated. There is also some apparent crowding out of weak plants. The number of plants counted per peck of seed sown ranged from 80,500 in the 10-peck seeding to 98,500 in the 4-peck seeding. The ratio of grain to straw was almost 1 to 1 except in the 8-peck seeding.

TABLE XXI.—Average agronomic data for oats grown in the rate-of-seeding experiments on dry land on the Belle Fourche Experiment Farm in 1909, 1910, 1912, 1913, 1915, and 1916.

Rate of seeding per acre.	Emergence to maturity.	Height.	Weight per bushel. ^a	Stand per acre. ^b	Yields per acre.	
					Grain.	Straw.
	Days.	Inches.	Pounds.	Plants.	Pounds.	Pounds.
4 pecks.....	83	26	31.2	394,000	1,273	1,275
6 pecks.....	82	26	32.1	525,000	1,298	1,315
8 pecks.....	81	25	32.7	672,000	1,213	1,319
10 pecks.....	80	23	32.8	805,000	1,190	1,213

^a Average for 4 years, 1909, 1913, 1915, and 1916.

^b Average for 3 years, 1909, 1915, and 1916.

EXPERIMENTS WITH BARLEY.

The yields of the best varieties of barley in pounds per acre on the Belle Fourche Experiment Farm have been nearly as large as those of oats and spring wheat. Most varieties of barley mature more quickly than oats or wheat, and the crop can thus be sown at a later

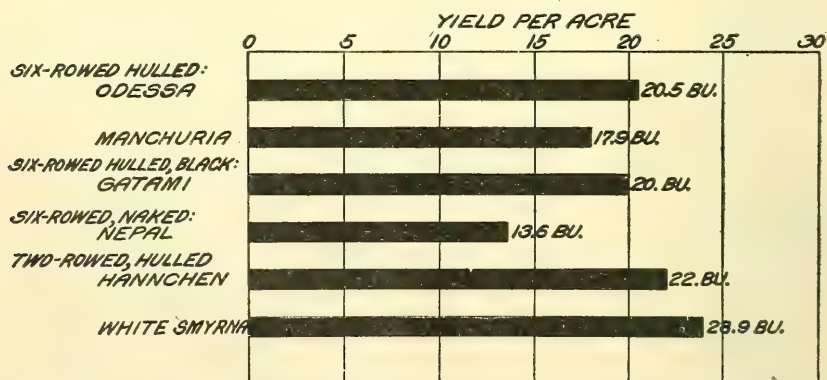


FIG. 11.—Diagram showing the average yields, in bushels per acre, of the leading varieties of barley on dry land at the Belle Fourche Experiment Farm for the 8-year period from 1912 to 1919, inclusive.

date. Barley grown on the dry lands of western South Dakota is used almost exclusively as a feed crop and its market value is of minor importance there.

Winter barley has been sown several years, but has never survived the winter at Newell.

VARIETAL EXPERIMENTS.

Since 1908 25 varieties and strains of barley have been grown in the varietal experiments. Only 1 variety has been grown during the entire period, but 4 varieties were grown continuously from 1909 to 1919, inclusive. The yields are shown in Table XXII. The average yields of 6 varieties of barley are also shown graphically in figure 11.

In Table XXII it can be seen that high yields of barley were obtained in 1915, and fair yields in 1908, 1909, 1916, 1917, and 1918. During the other seasons the yields either were small or else almost complete failures. These differences were chiefly influenced by the seasonal precipitation.

In general the 2-rowed varieties have produced the highest yields. Of the two leading 2-rowed varieties, White Smyrna has given the highest average yield. Because of its earliness this variety has yielded well in dry seasons, but the Hannchen variety yielded best in

favorable seasons. Heads of Hannchen and White Smyrna barley are shown in figure 12. The Odessa is the highest yielding 6-rowed



FIG. 12.—Heads of the two leading varieties of barley grown on dry land on the Belle Fourche Experiment Farm: 1, Hannchen; 2, White Smyrna.

variety which has been grown for a long period, but the Coast variety has a higher average yield during the years it has been grown. The Gatami variety yields well in dry seasons, but not especially well in favorable seasons. It has further objections in having black glumes and a very brittle peduncle. The Manchuria, which is the leading variety of barley in North Dakota, South Dakota, Minnesota and Wisconsin, has not yielded well at Newell. Three strains of this variety have been grown.

TABLE XXII.—*Yields of varieties of barley grown on dry land on the Belle Fourche Experiment Farm, 1908 to 1919, inclusive.*

Group and variety.	C. I. No.	Yields per acre (bushels).														
															Average.	
		1908	1909	1910	1911	1912	1913	1914	1915	1916	1917	1918	1919	1909 to 1919	1912 to 1919	1915 to 1919
Six-rowed, hulled:																
Coast.....	690								82.8	18.3	22.1	18.4	9.8			30.3
Odessa.....	182	22.1	8.1	0		9.8	8.7	3.5	69.4	26.1	18.3	20.0	8.0	17.6	20.5	28.8
Manchuria (Minn. No. 105).....	354					7.6	6.6									
Manchuria (Minn. No. 6).....	638	19.8	5.2	0		8.1	8.0	4.2	62.1	20.2	12.9	18.3	9.0	15.3	17.9	24.5
Manchuria.....	643	26.0	17.3	4.3	0	7.2										
Six-rowed, hulled, black:						18.3	8.2	6.9	50.6	28.2	26.0	14.4	7.1		20.0	25.3
Gatami.....	575															
Six-rowed, naked, awned:																
Himalaya (Guy Mayle).....	620								58.4	18.3	12.4	12.7	5.4			21.4
Six-rowed, naked, hooded:																
Nepal (White Hull-less).....	595	12.0	9.0	1.7	0	10.7	8.9	4.9	50.8	13.1	9.5	8.7	2.0	10.8	13.6	16.8
Do.....	262	16.3	9.6	2.5	0											
Two-rowed, hulled:																
Chevalier II.....	530	22.1	0	0	0	6.8	1.1									
Hanna.....	24	29.0	23.8	1.0	0	0	10.7	2.7								
Do.....	203	27.9	21.4	1.4	0	0										
Hannchen.....	531	19.2	3.1	0	0	12.7	6.7	85.9	23.5	17.5	23.6	6.1	18.0	22.0	31.3	
White Smyrna (Ouchac).....	658					10.7	14.3	14.4	76.2	24.6	23.3	18.4	9.2		23.9	30.3
Do.....	195								77.9							

The yields of the naked varieties Himalaya and Nepal have been much less than those of the hulled varieties. If the weights of the glumes are considered, the average yield of Himalaya has been equal to that of several of the hulled varieties, though not to the best. The Nepal is not sufficiently vigorous to be productive.

The average dates of heading and maturity, height, weight per bushel, and yields of grain and straw for four varieties of barley are shown in Table XXIII. The Hannchen variety shows a considerably later date of heading than the other varieties, but this is partly due to the failure of the heads to emerge promptly or fully from the sheath, even though they were well developed. The Hannchen has the heaviest weight per bushel and the highest yields of grain and straw. The Odessa and Manchuria varieties were taller than the Nepal and Hannchen.

TABLE XXIII.—Average agronomic data for four varieties of barley grown on dry land on the Belle Fourche Experiment Farm, 1909 to 1919, inclusive.

Group and variety.	C. I. No.	Date of—		Height. ^a	Weight per bushel. ^a	Yields per acre.	
		Head- ing. ^a	Matur- ity. ^a			Grain.	Straw. ^a
Six-rowed, hulled:				<i>Inches.</i>	<i>Pounds.</i>	<i>Bushels.</i>	<i>Pounds.</i>
Odessa.....	182	July 2	July 20	25	42.7	17.6	1,217
Manchuria (Minn. No. 6).....	638	July 5 ^b	July 22	24	42.4	15.3	1,048
Six-rowed, naked, hooded:							
Nepal (White Hull-less).....	595	July 3 ^c	July 24	21	57.4	10.8	1,053
Two-rowed, hulled:							
Hannchen.....	531	July 13 ^d	July 24 ^e	21	45.1	18.0	1,254

^a Average for 9 years, 1909, 1910, 1912 to 1917, and 1919.^b Average for 8 years, 1909, 1910, 1912, 1913, 1915 to 1917, and 1919.^c Average for 8 years, 1909, 1910, and 1912 to 1917.^d Average for 4 years, 1909 and 1915 to 1917.^e Average for 8 years, 1909, 1910, 1913 to 1917, and 1919.

NURSERY EXPERIMENTS.

The nursery experiments with barley consisted almost entirely of tests of varieties. No promising varieties not already being grown in plats were observed in the nursery experiments. Progenies from a few natural hybrids of barley found in the plats at Newell were grown for observation. The strains isolated were not as promising as other varieties previously mentioned.

RATE-OF-SEEDING EXPERIMENTS.

Rate-of-seeding experiments with White Smyrna barley, C. I. No. 658, were begun in 1917 and conducted for three years. The barley was sown at four different rates, ranging from 4 to 10 pecks per acre. The data are not entirely conclusive, but are of considerable interest. The yields are shown in Table XXIV.

The highest average yield was obtained from the plats sown at the rate of 4 pecks per acre. In 1917, however, the 8-peck rate gave the highest yield. The barley in the varietal experiments usually has been sown at the rate of 5 pecks per acre, and from the average results shown in Table XXIV this rate appears to be ample. On a well-prepared seed bed the sowing of 4 pecks of clean barley seed per acre apparently is sufficient.

TABLE XXIV.—Yields of White Smyrna barley grown in rate-of-seeding experiments on dry land on the Belle Fourche Experiment Farm, 1917 to 1919, inclusive.

Rate of seeding per acre.	Yields per acre (bushels).			
	1917	1918	1919	Average.
4 pecks.....	28.7	25.7	9.7	21.4
6 pecks.....	31.3	20.9	9.4	20.5
8 pecks.....	33.3	18.0	8.7	20.0
10 pecks.....	28.2	19.3	8.0	18.5

EXPERIMENTS WITH MINOR CEREALS.

The cereals of minor importance which were grown in experiments on dry land at Newell are proso, rye, emmer, spelt, buckwheat, and the grain sorghums.

The work with these, with the exception of proso, has not been very extensive.

SPRING EMMER.

One variety of spring emmer, Vernal (White Spring), has been grown on dry land each year since 1908. No crop was produced in 1911, 1912, and 1914. The highest yield, 3,513 pounds per acre, was obtained in 1915. Emmer is severely injured by extreme drought and under such conditions it yields considerably less than adapted varieties of barley. Table XXIX (p. 41), showing a comparison of yields of the various grain crops, presents the yields of Vernal emmer in pounds per acre for five years from 1913 to 1917, inclusive. Vernal emmer yielded an average of 1,179 pounds per acre, compared with yields of 1,378, 1,415, and 1,405 pounds per acre, respectively, for Kubanka wheat, Kherson oats, and Hannchen barley. Under conditions at Newell the better varieties of oats and barley may be expected to yield considerably more grain per acre than emmer.

WINTER EMMER AND SPELT.

Winter emmer has been grown in both the plat and nursery experiments on dry land. Black Winter emmer, C. I. No. 2337, was grown in plats in 1909, but only 1 per cent of the plants survived the winter. It has been grown in the nursery for several seasons since then, but the yields and winter survival were always low. Buffum Improved Black Winter emmer, C. I. No. 3331, was grown in plats from 1913 to 1917, inclusive. The crop was entirely winterkilled in 1917, and the spring survival was low in the other seasons, not more than one-third of the plants surviving even the mildest winters.

The yields of Buffum Improved Black Winter emmer are shown in Table XXIX (p. 41). The average yield for the 5-year period from 1913 to 1917, inclusive, was 639 pounds per acre, compared with 1,800 pounds of Kharkof winter wheat. Considering the low market and feeding value and the low winter survival and yield of the winter emmer, it can not be recommended for growing in western South Dakota.

A single variety of winter spelt was grown in 1917. This was a brown winter spelt, the seed of which had been imported from Switzerland, about 1913, by a farmer in the vicinity. Although this was slightly hardier than winter emmer, it was much inferior to winter wheat in both yield and value.

RYE.

Spring rye has not been grown at Newell except in 1908 and the crop was not very successful. Winter rye is considered much more promising. Winter rye was grown from 1913 to 1917, inclusive. Only one variety, Swedish (Minn. No. 2), C. I. No. 137, has been grown in plats on dry land. In 1913 this was injured at flowering time by hot winds, which caused considerable floret sterility and also before maturity by a hailstorm which shattered much of the grain. The 1914 and 1917 crops were reduced by drought, the 1915 crop was slightly injured by rust, and the 1916 crop by both drought and rust. The yields ranged from 5.3 bushels in 1913 to 44.5 bushels per acre in 1915. The 5-year yield is 20.6 bushels per acre. The yield of Swedish winter rye in pounds per acre in comparison with winter wheat and several spring grains is shown in Table XXIX (p. 41). The rye has yielded less than winter wheat, spring wheat, oats, and barley, and is consequently considered a less profitable crop to grow. However, it is hardier and more certain than winter wheat and can be sown later. The greater hardiness of winter rye is shown in figure 8. Rye may be drilled in small grain stubble in the fall, with fair chances of obtaining a crop of grain or hay.

Two other varieties of winter rye have been grown in nursery experiments. One of these, North Dakota No. 959, is very hardy, but neither this nor the other variety, known as C. I. No. 178, yielded as well as the Swedish variety.

BUCKWHEAT.

The growing of buckwheat on dry land was attempted only in 1908. No seed was matured. Apparently buckwheat is not adapted to growing under the dry conditions which usually prevail at Newell.

PROSO.

Proso,⁹ or hog millet, is an early maturing millet the seed of which is used for grain. It is best adapted to the northern Great Plains and prairie sections, where it is grown to a limited extent as a catch crop. It is well suited to the climatic conditions in South Dakota. Other spring cereals on the average produce more grain per acre than proso, but in some seasons proso has outyielded all other spring grain crops. It can be sown even as late as July 1 and still mature seed.

VARIETAL EXPERIMENTS.

Varietal experiments with proso were begun in 1908, when a few varieties were grown in plats and several others in rows. From 1909

⁹ For further information concerning proso, see Farmers' Bulletin 1162, "Proso, or hog millet," by John H. Martin, 15 p., 4 fig. 1920.

to 1915, inclusive, because of the minor importance of the crop, the proso varieties were grown only in rows. These rows usually were 60 feet long and replicated two or three times. During this period the highest average yields were obtained from the Turghai and Red Russian varieties.

In 1916 a few of the leading varieties of proso from the nursery row experiments were sown in plats. These were continued for three years more and several additional varieties also were grown in 1917 and 1919. The Dakota Kursk, a millet of the foxtail group, was included in both the nursery and plat experiments for comparison with the prosos. The yields of the varieties are shown in Table XXV.

TABLE XXV.—*Yields of proso varieties grown on dry land on the Belle Fourche Experiment Farm, 1916 to 1919, inclusive.*

Group and variety.	C. I. No.	Yields per acre (bushels).				
		1916	1917	1918	1919	Average.
Spreading, white seeded:						
White Ural.....	4	24.1	23.7	44.3	5.5	24.4
"White".....	78		11.8		5.8	
Hansen.....	179	27.2	18.8	33.6	9.7	22.3
Spreading, red seeded:						
Red Russian.....	61	25.0	17.5	55.4	13.2	27.8
Turghai.....	31	21.4	18.2		13.1	
Loose, yellow seeded:						
Yellow Manitoba.....	101		15.4		11.3	
Loose, black seeded:						
Black Voronezh.....	27	^a 23.5	16.4	38.8	14.0	23.2
Compact, red seeded:						
Red Voronezh.....	26		15.4		8.9	
Yellow Sarepta.....	17		13.6		9.2	
Foxtail millet:						
Dakota Kursk.....			6.3		12.8	

^a Grown in a spacing test adjoining other varieties.

As shown in Table XXXVI, the Red Russian variety produced the highest average yield during the 4-year period. The White Ural, the next highest yielding variety, produced 3.4 bushels per acre less than Red Russian. Both the Black Voronezh and the Hansen yielded less than the White Ural. The Turghai was the highest yielding variety in the nursery experiments, but it did not yield as well as Red Russian in the plat experiments. It was not grown in plats in 1918, however.

Average agronomic data for the proso varieties grown in 1917 and 1919 are shown in Table XXVI.

TABLE XXVI.—Average agronomic data for the proso varieties grown in plats on dry land on the Belle Fourche Experiment Farm in 1917 and 1919.

Group and variety.	C. I. No.	Date of—		Height.	Weight per bushel.	Yields per acre.	
		Heading.	Maturity.			Seed.	Straw.
Spreading, white seeded:				<i>Inches.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
White Ural.....	4	Aug. 8	Aug. 22	18	53.6	817	1,212
Hansen.....	179	do.	Aug. 23	23	54.1	797	1,012
Spreading, red seeded:							
Red Russian.....	61	Aug. 9	Aug. 24	24	55.7	861	1,300
Turghai.....	31	Aug. 11	Aug. 29	25	55.8	876	1,762
Loose, yellow seeded:							
Yellow Manitoba.....	101	do.	do.	29	55.5	748	1,300
Loose, black seeded:							
Black Voronezh.....	27	Aug. 12	Aug. 31	29	57.0	851	1,533
Compact, red seeded:							
Red Voronezh.....	26	Aug. 10	Aug. 26	20	55.8	681	1,037
Yellow Sarepta.....	17	do.	Aug. 25	20	56.2	639	937
Fortail millet:							
Dakota Kursk.....		Aug. 26	Sept. 16	20	52.2	535	1,180

RATE-OF-SEEDING EXPERIMENTS.

A rate-of-seeding experiment with Hansen proso was conducted on dry land in 1917. The experiment was sown at three different rates, in triplicate, on June 19. The plats sown at 15 pounds per acre yielded an average of 20.3 bushels, those sown at 22.5 pounds yielded 22.3 bushels, while those sown at 30 pounds yielded 23.0 bushels per acre. It is thus seen that the 30-pound rate gave a slightly higher net yield than the 22.5-pound rate. Under conditions of earlier seeding or late drought a thinner seeding might have given the highest yield. Conclusions can not be drawn from a 1-year experiment, but apparently not less than 25 to 30 pounds of proso should be sown per acre for best results under the conditions at Newell.

SPACING EXPERIMENTS.

Black Voronezh proso was grown in an experiment in 1916 and 1917 to determine the distance between drill rows which would produce maximum yields. The seed was sown with the grain drill in rows 7, 14, and 21 inches apart in triplicated plats. The drill was set in the same notch for all spacings, so that the plats having rows 7 inches apart were sown at the rate of about 28 pounds per acre, those with rows 14 inches apart at the rate of 14 pounds per acre, and those in rows 21 inches apart at about 8.5 pounds per acre. The yields from the experiment are shown in Table XXVII.

TABLE XXVII.—*Yields of Black Voronezh proso grown in spacing experiments on dry land on the Belle Fourche Experiment Farm in 1916 and 1917.*

Distance between rows.	Yields per acre, bushels.		
	1916	1917	Average.
7 inches.....	26.1	24.4	25.2
14 inches.....	23.5	20.9	22.2
21 inches.....	16.0	16.7	16.3

The average yield from the plats sown in the regular 7-inch drill rows was 25.2 bushels, from the 14-inch rows 22.2 bushels, and from the 21-inch rows 16.3 bushels per acre. Proso has rather coarse stems and spreading branches, and it was thought that the wider spacing might show a slight advantage. The yields, however, were strongly in favor of the thick spacing. Unfortunately, the rates of seeding were different with each spacing, but the results obtained in this and the rate-of-seeding experiment previously described seem to indicate that proso should be sown in drill rows about 7 or 8 inches apart at a rate not less than 25 to 30 pounds per acre.

EXPERIMENT WITH GRAIN SORGHUMS.

One or more varieties of grain sorghum were sown at Newell each year from 1908 to 1917, except in 1911, when the soil was too dry for the seed to germinate. Most types did not produce seed and did not always form heads because of the cool weather. The only varieties which matured seed were extremely early, and included Manchu Brown kaoliang, Dwarf milo, and Freed sorgo. The Dwarf milo produced seed only in 1913. The yields of the leading grain-sorghum varieties are shown in Table XXVIII.

TABLE XXVIII.—*Yields of the leading varieties and strains of grain sorghum grown on dry land on the Belle Fourche Experiment Farm, 1908 to 1917, inclusive.*

Group and variety.	C. I. No.	Yield per acre (bushels).									Average, 1903 to 1917.
		1908 ^c	1909 ^b	1910 ^a	1912	1913 ^b	1914 ^c	1915 ^c	1916 ^c	1917 ^d	
Kaoliang:											
Manchu Brown.....	171	22.9		7.1	0	5.0	4.6	0	0		
Manchu Brown Selection 3-1.	261		18.9		0	6.2	3.5	0	0		
Manchu Brown Selection 3-5.	261		13.2	12.2	0	4.6	1.5	0			
Manchu Brown Selection 4....	261		12.3	11.6	0	6.2	2.5	0	0		
Manchu Brown.....	328		9.4	8.0	0	4.2	6.6	0	0	23.6	6.5
Milo:											
Dwarf.....						5.0	0	0	0		
Sorgo:											
Freed.....						5.8	6.0	0	0		

^a Yield calculated from that of an 80-foot row.

^b Yield calculated from that of a 132-foot row.

^c Yield calculated from that of two 132-foot rows.

^d Yield calculated from that of a tenth-acre plat.

Strains of Manchu Brown kaoliang produced the highest yields during all of the years from 1909 to 1916, inclusive. Complete failures were recorded in 1912, 1915, and 1916, on account of early frosts which killed the plants before the grain was ripe. Drought and frost caused low yields in all other years except 1917, when a yield of 23.6 bushels of nearly mature kaoliang was obtained. The grain sorghums have yielded less than any of the other grains at Newell and are not adapted to the prevailing climatic conditions.

COMPARISON OF GRAIN CROPS.

A comparison of the yields in pounds per acre of all grains on the dry land at Newell are shown in Table XXIX. The yields shown are for the 5-year period from 1913 to 1917, inclusive, when nearly all of the small grains were being grown in plats. For the entire period of the cereal experiments at Newell the comparative yields of the crops would be somewhat different. The crops were not all grown under comparable conditions each year. However, the rye, winter emmer, and spelt were sown in the same series and on the same date as the winter wheat. The yields of spring wheat shown were obtained from replicated plats sown in the winter-wheat series each spring. The spring emmer was grown along with the barley varieties. The oats usually were sown in the same series with barley. The proso and kaoliang usually were sown on the same date and on adjoining land.

TABLE XXIX.—*Yields of the leading varieties of different grain crops grown on dry land on the Belle Fourche Experiment Farm from 1913 to 1917, inclusive.*

Crop, group, and variety.	Yields per acre (pounds).						Average.
	C. I. No.	1913	1914	1915	1916	1917	
Crimean winter wheat:							
Kharkof.....	1442	2,316	1,722	3,828	852	282	1,800
Durum spring wheat:							
Kubanka.....	1440	1,074	1,014	2,940	1,014	846	1,378
Winter emmer:							
Buffum Black Winter.....	3331	1,035	1,248	848	625	0	639
Spring emmer:							
Vernal (White Spring).....	1524	500	0	3,513	1,100	781	1,179
Winter spelt:							
Brown Winter.....						100	.....
Winter rye:							
Swedish (Minn. No. 2).....	137	296	890	2,497	1,116	980	1,156
Spring oats:							
Kherson.....	459	700	442	3,547	1,305	1,081	1,415
Spring barley:							
Hannchen.....	531	609	321	4,123	1,133	840	1,405
Proso:							
Red Russian.....	61	0	^a 704	^a 1,368	1,400	980	890
Kaoliang:							
Manchu Brown.....	328	244	383	0	0	1,368	399

^a Yields from two 60-foot rows.

The average yield of Kharkof winter wheat during the five years was 1,800 pounds per acre. Kherson oats yielded at the rate of 1,415 pounds per acre, Hannchen barley 1,405 pounds, and Kubanka spring wheat at the rate of 1,378 pounds per acre. Other cereal crops yielded less than the spring wheat. The period from 1913 to 1917 was usually favorable for winter wheat, but this crop, although rather uncertain, may be expected to yield more than other cereals on the average. The yields in pounds per acre of well-adapted varieties of spring wheat, oats, and barley are nearly the same. The Manchu Brown kaoliang, because of its resistance to early drought, outyielded all other crops in 1917. In 1916 the Red Russian proso produced more grain than the other crops. This was

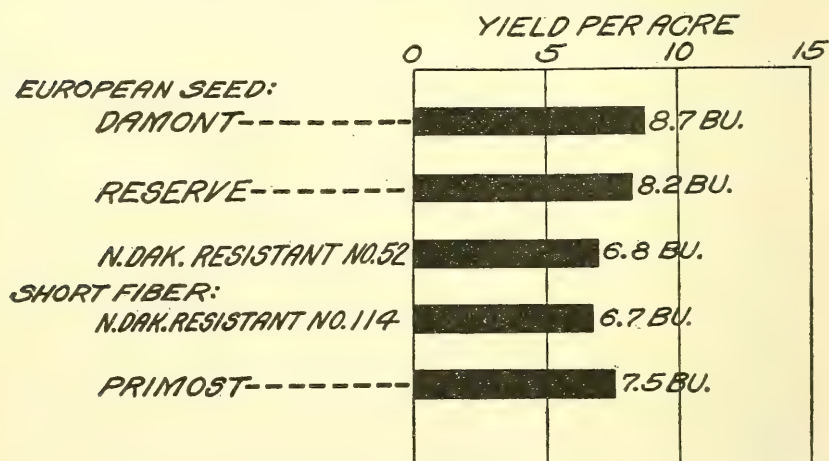


FIG. 13.—Diagram showing the average yields, in bushels per acre, of the leading varieties of flax on dry land at the Belle Fourche Experiment Farm for the 6-year period from 1914 to 1919, inclusive.

partly because the kaoliang was frosted, while the other crops were injured by rust, soil blowing, or drought.

EXPERIMENTS WITH FLAX.

Flax is a crop usually grown on new sod land. However, when grown in rotation on land fairly free from weeds it can be grown successfully on land which has been previously cropped. The yields of flax at Newell have compared rather favorably with the small grains when the value of the crop is considered. Flax is less certain than the small grains, as it is more easily injured by drought, frost, and soil blowing.

VARIETAL EXPERIMENTS.

The varietal experiments with flax were begun in 1912. Twelve varieties have been grown in plats on dry land during the period

of the experiments, but only three varieties were grown all of the seasons. Good yields of flax were obtained in 1912, 1915, and 1918, fair yields in 1916 and 1917, and poor yields in 1913 and 1914, while the crop was a complete failure in 1919. The yields depended chiefly upon the seasonal precipitation. Very little injury from diseases was observed. The yields are shown in Table XXX.

It will be observed (Table XXX) that the Damont variety, C. I. No. 3, gave the highest average yields during both the 6-year and 8-year periods. The next highest yields were obtained from the Reserve variety, C. I. No. 19. This variety was formerly known as Russian and North Dakota No. 155. The wilt-resistant varieties, North Dakota Resistant Nos. 52 and 114, have not yielded as well as the other varieties. None of the varieties has been reduced in yield by wilt injury. The average yields of the flax varieties from 1914 to 1919, inclusive, are shown in figure 13.

TABLE XXX.—Yields of flax varieties grown on dry land on the Belle Fourche Experiment Farm, 1912 to 1919, inclusive.

Group and variety.	C. I. No.	Yields per acre (bushels).									Average.	
		1912	1913	1914	1915	1916	1917	1918	1919		1912 to 1919.	1914 to 1919.
European seed:												
Select Russian (N. Dak. No. 608).....	1	10.6	3.3	2.2	.....	.....	.....	.....	.....	.....	.....	.....
Select Riga (N. Dak. No. 1214).....	2	10.6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Damont (N. Dak. No. 1215).....	3	11.2	5.6	.7	23.6	7.6	7.2	13.1	0	8.6	8.7	.....
Kazan (N. Dak. No. 1329).....	4	8.2	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Stepan (N. Dak. No. 1340).....	5	0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Frontier (N. Dak. No. 155).....	17	7.5	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Reserve.....	19	8.9	5.2	.8	22.0	7.7	6.9	11.6	0	7.9	8.2	.....
N. Dak. Resistant No. 52.....	8	.....	4.5	2.4	12.3	7.1	6.2	12.9	0	.....	6.8	.....
Short fiber:												
N. Dak. Resistant No. 114.....	13	.....	.....	1.5	16.7	5.8	6.3	10.1	0	.....	6.7	.....
Primost (Minn. No. 25).....	12	9.1	4.8	1.7	17.8	6.2	6.9	12.4	0	7.4	7.5	.....
Turkish:												
Turkish.....	7	11.4	2.8	2.4	.....	.....	.....	.....	.....	.....	.....	.....
Smyrna.....	30	.....	.....	.....	18.1	2.9	.....	.....	.....	.....	.....	.....

a Reseeded, first seeding failed to emerge.

RATE-OF SEEDING EXPERIMENTS.

Rate-of-seeding experiments with flax on dry land were conducted in 1912 and again from 1915 to 1918, inclusive. The variety used was "common" flax in 1912, Primost in 1915 and 1916, and Damont in 1917 and 1918. Except in 1912, sowings were made at three rates, viz, 15, 22.5, and 30 pounds per acre. The highest average yields were obtained from the plats sown at the rate of 30 pounds per acre. During the five years, 1912 and 1915 to 1918, inclusive, the 30-pound rate gave an average yield of 0.8 bushel per acre more than the 15-

pound rate. The net increase for the 30-pound rate is only about 0.5 bushel, which probably is not significant. However, these experiments were all conducted on a well-prepared seed bed, and probably the results from the 15-pound rate are better than would be obtained under ordinary seed-bed conditions. The best rate of sowing for flax on dry land at Newell probably is about 2 pecks (28 pounds) per acre. The data from the rate-of-seeding experiments are shown in Table XXXI.

TABLE XXXI.—*Yields of flax^a grown in rate-of-seeding experiments on dry land on the Belle Fourche Experiment Farm in 1912 and from 1915 to 1918, inclusive.*

Rate of seeding per acre.	Yields per acre (bushels).						
	1912	1915	1916	1917	1918	Average.	
						1915 to 1918	1912 and 1915 to 1918
15 pounds.....	9.6	23.6	8.2	7.8	9.2	12.2	11.7
22½ pounds.....		25.6	8.4	7.8	7.9	12.4	
30 pounds.....	11.2	27.0	7.2	7.4	9.5	12.8	12.5

^a Common flax used in 1912; Primost, C. I. No. 12, in 1915 and 1916; and Damont, C. I. No. 3, in 1917 and 1918.

TABLE XXXII.—*Yields of flax grown in date-of-seeding experiments on dry land on the Belle Fourche Experiment Farm, 1912, 1913, and 1915 to 1919, inclusive.*

Date of seeding.	Yields per acre (bushels).						
	1912	1913	1915	1916	1917	1918	Average, 1917 to 1918.
April 20 to 25.....				(a)	5.8	9.2	7.5
May 2 to 8.....		7.7	20.0	6.3	5.3	10.8	8.0
May 15 to 20.....	8.3				5.5	11.4	8.4
May 20 to 25.....		4.8	21.5	6.9			
June 1 to 10.....	10.6	3.0	(b)		4.2	6.5	5.4

^a Early seeding blown out.

^b Did not emerge.

DATE-OF-SEEDING EXPERIMENTS.

Date-of-seeding experiments with flax were conducted in 1912, 1913, and 1915 to 1918, inclusive. The Primost variety (C. I. No. 12) was grown in 1912, 1913, and 1915 and Damont (C. I. No. 3) in 1916, 1917, and 1918. Sowings were made on two, three, or four dates each season. The dates of seeding were not the same each year, because the soil frequently was too wet when the sowings should have been made. Because of the variable seasons and the irregularities in the experiment it is difficult properly to summarize

the yield data. In 1913 and 1917 the earliest dates of seeding gave the highest yields; in 1912, 1915, and 1916 the latest dates gave the highest yields, while in 1918 the medium dates were most favorable. The flax in the last sowing in 1915 did not emerge and that from the earliest sowing of 1916 was blown out. Late summer rains in 1912 favored late sowing of flax, but in general the yields from flax sown after May 20 were comparatively low. The best date of seeding for flax on dry land at Newell, although undetermined, probably occurs between April 15 and May 15. The data are shown in Table XXXII.

EXPERIMENTS ON IRRIGATED LAND.

In 1912 a large part of the Belle Fourche Experiment Farm was placed under irrigation, and experiments with cereals on the irrigated land were begun at that time. A few varieties of spring wheat, oats, barley, and flax were sown on irrigated land in 1912, 1913, and 1914. In 1915 the number of plats was increased to include experiments with winter wheat and grain mixtures, and in 1916 and thereafter a number of additional experiments were in progress. The irrigated plats were one twenty-fifth of an acre each in 1912 and 1913, but in 1914 and thereafter nearly all experiments were conducted in triplicated fiftieth-acre plats.

Most of the cereals grown under irrigation were sown on land which had produced an intertilled crop, such as corn, potatoes, roots, or sunflowers, the previous year. The land was double disked and harrowed or "floated" before seeding. The cereal crops received two and sometimes three irrigations during the season. The time of irrigation was gauged by the condition of the soil rather than by the stage of growth of the grain, because it was practically useless to irrigate until the surface soil was sufficiently dry and cracked to take up water. The quantity of water applied was not measured, but was approximately 4 or 5 acre-inches at each application. Water was applied by flooding from field ditches, which usually were constructed along the ends of the plats.

The average yields from the irrigated land are not greatly in excess of those from the same crops grown on the dry land. In 1915 the yields on dry land were much higher than on irrigated land.

From 1912 to 1915, inclusive, the irrigation experiments were conducted on rather unfavorable soil, while in 1916 most of the crops were damaged by soil blowing and rust. The irrigated grains were sown on previously cropped land following either small grain or an intertilled crop, while many of the dry-land experiments were conducted on summer fallow. In most seasons the grains were sown on the dry land earlier than on the irrigated land, chiefly because the

soil was dry enough to be in condition for seeding before the irrigated land. This favored higher yields from the dry land.

On the whole, the yields from the cereal plats on irrigated land are considerably higher than the average for the region, where the conditions, as on the Belle Fourche Experiment Farm, usually are not favorable for maximum grain yields.

EXPERIMENTS WITH WHEAT.

SPRING WHEAT.

VARIETAL EXPERIMENTS.

Ten varieties of spring wheat have been grown in the experiments on irrigated land. Three of these were grown during the entire period from 1912 to 1919. The experiments were on rather poor soil from 1912 to 1915. The seeding was late in 1915. In 1916 the wheat

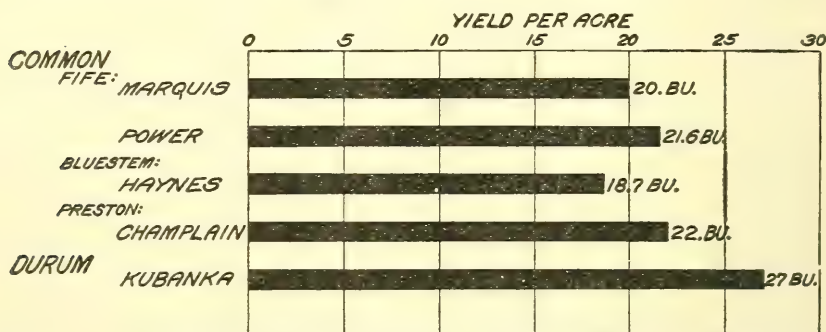


FIG. 14.—Diagram showing the average yields, in bushels per acre, of the leading varieties of spring wheat on irrigated land at the Belle Fourche Experiment Farm for the 6-year period from 1914 to 1919, inclusive.

was damaged by soil blowing and also was severely attacked by rust. Good yields of most varieties of spring wheat were obtained in 1917, 1918, and 1919. The yields of the spring-wheat varieties on irrigated land are shown in Table XXXIII. The average yields for six years also are shown in figure 14.

The average yield of the Kubanka variety during the 8-year period, 1912 to 1919, inclusive, was 25.2 bushels per acre. During this same period Power yielded 20.8 bushels and Haynes Bluestem 18.6 bushels per acre. During the 6-year period, 1914 to 1919, inclusive, Kubanka yielded an average of 27 bushels per acre. The next highest yielding variety was Champlain, which produced 22 bushels per acre. Marquis during this period yielded only 20 bushels per acre. This was partly due to poor growth in 1917 and 1919. In 1917 the Marquis was sown at 4 pecks per acre, by mistake, while the other varieties were sown at the rate of 5 pecks per acre. The

average yield of Power is 1.6 bushels per acre higher than Marquis, but because of the irregularities just mentioned this difference may not be significant. Marquis is the leading variety of wheat in the vicinity of Newell and, because of its high quality, earliness, and short, strong straw, is probably to be preferred to other common wheats for growing on irrigated land. The Kubanka, a durum wheat, has outyielded all other varieties to such an extent as to make it the most profitable variety. Even at the lower price obtained for irrigated durum wheat, the net return doubtless will be higher than from any of the common wheats.

TABLE XXXIII.—Yields of the varieties of spring wheat grown on irrigated land on the Belle Fourche Experiment Farm, 1912 to 1919, inclusive.

Class, group, and variety.	C. I. No.	Yields per acre (bushels).									
		1912 ^a	1913	1914	1915	1916	1917	1918	1919	Average.	
										1912 to 1919	1914 to 1919
COMMON.											
Fife:											
Marquis.....	3276	.....	18.3	18.3	18.0	9.4	20.1	35.0	19.4	.....	20.0
Power.....	3025	19.5	17.0	17.0	14.7	8.4	27.3	35.0	27.5	20.8	21.6
Saskatchewan Fife.....				14.9	12.1						
Ghirka Spring.....	1517	16.4	.....	.....	.....	.....	.....	.....	.....	.....	.....
Bluestem:											
Haynes Bluestem.....	2874	22.0	14.2	15.4	11.5	7.3	19.8	30.7	27.5	18.6	18.7
Preston:											
Champlain.....	4872	.....	.....	19.0	12.2	6.5	29.5	37.6	27.3	.....	22.0
Unclassified:											
Regenerated Defiance.....	3703	.....	11.7	18.0	8.0	2.0	.....	.....	.....	.....	.....
Dicklow.....	3663	.....	.....	.....	.....	.....	.....	.....	19.4	.....	.....
DURUM.											
Acme.....	5284	.....	.....	.....	.....	.....	.....	39.2	26.1	.....	.....
Kubanka.....	1440	20.8	18.6	22.8	22.0	20.6	25.2	41.7	29.7	25.2	27.0

^a Grown in single plats in 1912.

^b Sown at a lower rate.

The Haynes Bluestem variety is late, easily injured by rust, easily shattered when ripe, and a rather poor yielder. The average yield of this variety during the 8-year period is 6.6 bushels per acre less than Kubanka.

The Champlain variety, also called Pringle's Champion, is an awned variety having semihard to hard red kernels. This wheat is apparently of lower quality than Marquis, Power, or Haynes Bluestem.

Two varieties of white wheats have been grown, but without much success. The Regenerated Defiance was severely injured by rust in both 1915 and 1916 and was discontinued from the experiments. The Dicklow variety, a soft white wheat extensively grown under irrigation in Idaho, was included in the experiments in 1919 only. It was outyielded by all varieties except Marquis, which yielded the same.

The Acme variety, a rust-resistant durum wheat originated at the Highmore (S. Dak.) substation, has not yielded as well as Kubanka under irrigation.

TABLE XXXIV.—Average agronomic data for five varieties of spring wheat grown on irrigated land on the Belle Fourche Experiment Farm, 1914 to 1917, inclusive, and in 1919.

Class, group, and variety.	C. I. No.	Date of—		Height.	Weight per bushel.	Yields per acre.	
		Heading.	Maturity.			Grain.	Straw.
COMMON.							
Fife:				<i>Inches.</i>	<i>Pounds.</i>	<i>Bushels.</i>	<i>Pounds.</i>
Marquis.....	3276	July 13	Aug. 8	29	58.3	17.0	1,409
Power.....	3025	July 15	Aug. 10	31	58.6	19.0	1,729
Bluestem:							
Haynes Bluestem.....	2874	July 17	Aug. 14	35	56.0	16.3	1,666
Preston:							
Champlain.....	4872	July 14	Aug. 10	33	57.7	18.9	1,511
DURUM.							
Kubanka.....	1440	July 12	Aug. 11	35	62.3	24.1	1,708

Table XXXIV shows the average dates of heading and maturity, the average height, weight per bushel, and yields of grain and straw of five of the varieties of spring wheat grown from 1914 to 1917, inclusive, and in 1919. The Marquis variety is the earliest and shortest. The Haynes Bluestem averaged six days later in maturity than Marquis and gave the lowest weight per bushel of any of the varieties. Kubanka, a durum wheat, had an average weight per bushel of 62.3 pounds.

NURSERY EXPERIMENTS.

The nursery experiments with spring wheat on the irrigated land consisted in the growing of a considerable number of foreign varieties in preliminary row tests. Nothing of unusual value was observed in the experiments.

WINTER WHEAT.

VARIETAL EXPERIMENTS.

The varietal experiments with winter wheat under irrigation were begun in the fall of 1914, when seven varieties and strains were sown. The wheat was sown on land which had been both irrigated and summer-fallowed and was thus in excellent condition for producing a crop. The resulting yields were quite large, but this was partly due to the very favorable season of 1915.

In 1916 and 1918 the winter-wheat varieties were sown on cornland which was irrigated, disked, and harrowed before seeding. Figure 15 shows construction of a ditch to irrigate the cornland before sowing winter wheat. The 1916 crop was greatly reduced by

stem rust. The wheat did not fully emerge in the fall of 1917. The 1917 crop was sown on beet land which had previously produced alfalfa. The wheat was partly destroyed by an accidental flooding late in the fall. Although the stands were thin the yields were fairly high in 1917.

The annual and average yields are shown in Table XXXV.



FIG. 15.—Constructing an irrigation ditch on the Belle Fourche Experiment Farm. The corn ground is irrigated before sowing it to winter wheat.

TABLE XXXV.—*Yields of varieties of winter wheat grown on irrigated land on the Belle Fourche Experiment Farm, 1915 to 1918, inclusive.*

Group and variety.	C. I. No.	Yields per acre (bushels).				
		1915	1916	1917	1918	Average.
Crimean:						
Beloglina.....	1667	^a 52.1	8.7	30.7	24.0	28.9
Kharkof.....	1583	66.3	11.3	29.5	23.4	32.6
Do.....	4207	61.3				
Turkey.....	3055	8.7	26.7	24.3		
Turkey selection.....	3055-159	66.6	11.5	31.0	26.5	33.9
Alton:						
Alton (Ghirka Winter).....	1438		8.8	19.9		
Alton selection.....	5297	59.1	5.2	28.5	26.5	29.8
Do.....	5298	57.5				
Do.....	1437-394	51.9				

^a One plat only.

In Table XXXV it will be observed that the Turkey selection, No. 3055-159, produced the highest yield each year. This strain

averaged 1.3 bushels per acre more than Kharkof, C. I. No. 1583, and also considerably outyielded the parent variety, Turkey, C. I. No. 3055, during the three years the latter was grown. The Beloglina yielded nearly as much as the other Crimean strains except in 1915, when only a single plat of that variety was grown, this being in an unfavorable location.

The awnless strains of the Alton (Ghirka Winter) group yielded less than the awned varieties of the Crimean group. The Alton variety was grown only in 1916 and 1917 and did not appear promising. Three other strains or selections of a type similar to Alton have been grown. Only one, C. I. No. 5297, an awnless selection or separation from Kharkof, was grown during each of the four years. Although this variety yielded somewhat less than Kharkof, it has the advantage of being awnless and is probably nearly equal to Kharkof in quality.

RATE-OF-SEEDING EXPERIMENTS.

Rate-of-seeding experiments with Kharkof wheat, C. I. No. 1442, were begun in the fall of 1915. The wheat was sown in triplicated fiftieth-acre plats at the rates of 3, 4, 5, and 6 pecks per acre. Results were obtained during three seasons.

The wheat was badly rusted in 1916, under which conditions the highest yields were obtained from the thickly sown plats. In 1917 and 1918 emergence was late and the stands of wheat were thin in the spring. The wheat was sown rather late during each of the three seasons, because of having to wait for the removal of the corn or root crop before preparing the land for wheat.

The yields are shown in Table XXXVI.

TABLE XXXVI.—*Yields of Kharkof winter wheat grown in rate-of-seeding experiments on irrigated land on the Belle Fourche Experiment Farm, 1916 to 1918, inclusive.*

Rate of seeding per acre.	Yields per acre (bushels).			
	1916	1917	1918	Average.
3 pecks.....	8.3	33.1	23.6	21.7
4 pecks.....	10.1	34.0	28.0	24.0
5 pecks.....	10.2	33.5	31.4	25.0
6 pecks.....	10.7	31.6	29.7	24.0

The highest average yield was obtained from the plats sown at the rate of 5 pecks per acre. The 6-peck rate gave the highest yield in 1916, the 4-peck rate in 1917, and the 5-peck rate in 1918. When the wheat is sown late the rate of seeding should be 5 pecks per acre. A seeding of less than 4 pecks per acre may be expected to cause reduced yields.

DEPTH-OF-SEEDING EXPERIMENTS.

Depth-of-seeding experiments with Kharkof winter wheats were conducted on irrigated land in 1917 and 1918. Only one fiftieth-acre plat was sown at each depth in 1917, but in 1918 the experiment was triplicated. The yields are shown in Table XXXVII.

TABLE XXXVII.—*Yields of Kharkof winter wheat grown in depth-of-seeding experiments on irrigated land in 1917 and 1918.*

Depth of seeding.	Yields per acre (bushels).		
	1917	1918	Average.
1 inch.....	24.5	35.9	30.2
1½ inches.....	30.0	34.2	32.1
2 inches.....	28.5	32.3	30.4

In 1917 the seeding at a depth of 1½ inches gave the highest yield, while in 1918 the highest average yield was obtained from seeding at a depth of 1 inch. The 1½-inch depth of seeding gave the highest average yield for the two years and, although the results are not very conclusive, this appears to be the most favorable depth.

COMPARISON OF SPRING AND WINTER WHEATS.

In 1916, 1917, and 1918, three plats of Kubanka durum spring wheat were sown in the spring in the same series with the winter-wheat varieties for comparison. During each of these years Kubanka considerably outyielded all of the winter-wheat varieties. In 1915 the winter wheat was sown under very favorable soil conditions and the yield was unusually high. The 4-year average yield of Kharkof, C. I. No. 1583, winter wheat was 32.6 bushels per acre, while Kubanka spring wheat yielded an average of 27.3 bushels. Because of the conditions in 1915, however, these yields are not quite comparable.

In the irrigated rotation experiments on the Belle Fourche Experiment Farm, conducted by the Office of Western Irrigation Agriculture, spring and winter wheat have been grown in continuous culture in adjoining plats each year since 1913. Since 1915 this test has been duplicated in another part of the rotation field on better soil. The yields on this good soil have been nearly twice as high as on the poorer soil. The average yields from the good and poor plats are used for comparison from 1915 to 1919, inclusive. The same variety of spring wheat was not used during all seasons. From 1913 to 1915, inclusive, Regenerated Defiance, C. I. No. 3703, was the variety used. In 1916 Marquis, C. I. No. 3276, was sown, but since 1917 Kubanka durum spring wheat was used. Because of the

greater yielding power and rust resistance of Kubanka, the yields of spring wheat doubtless would have been much higher had this variety been sown in the earlier years of the experiment.

The annual and average yields of spring and winter wheat in these experiments are shown in Table XXXVIII.

TABLE XXXVIII.—*Yields of winter and spring wheat varieties grown continuously in adjoining plats on irrigated land on the Belle Fourche Experiment Farm, 1913 to 1919, inclusive.^a*

Group.	Yields per acre (bushels). ^b							
	1913	1914	1915	1916	1917	1918	1919	Average.
Winter	7.7	29.4	32.7	10.9	18.1	19.2	12.4	18.6
Spring ^c	15.5	19.2	20.0	8.6	24.5	17.4	13.4	16.9

^a Data from rotation experiments of the Office of Western Irrigation Agriculture.

^b Single plats in 1913 and 1914; average of two plats, 1915 to 1919, inclusive.

^c Regenerated Defiance, C. I. No. 3703, in 1913, 1914, and 1915; Marquis, C. I., No. 3276, in 1916; and Kubanka, C. I., No. 1440, in 1917, 1918, and 1919.

Winter wheat outyielded spring wheat in these experiments in four out of seven years. The 7-year average yield of Turkey winter wheat was 18.6 bushels per acre. The adjoining plats of spring wheat produced an average yield of 16.9 bushels during the same period. In general, winter wheat may be slightly more productive than spring wheat under irrigation, but in many seasons the reverse is true. Winter wheat is not as well suited to growing under irrigation as spring wheat because of the rotation scheme. Wheat on irrigated land is usually sown after an intertilled crop, such as corn, roots, or potatoes. These crops are usually not removed from the ground until rather late for sowing winter wheat. When winter wheat is sown following a small-grain crop, it is necessary to plow and irrigate the land rather promptly after the previous crop is thrashed. Spring wheat also is a more convenient nurse crop for alfalfa, sweet clover, or grasses, which frequently are sown with the grain.

EXPERIMENTS WITH OATS.

VARIETAL EXPERIMENTS.

The experiments with oat varieties under irrigation were begun in 1912. Fifteen varieties have been grown in plats, but only four of these were grown during all of the eight years. Fair or good crops were obtained each season, but the yields are not large. The crop was almost free from diseases or other injury, so that the yields were chiefly limited by the character of the growing season, seed bed, and soil fertility. The yields of the oat varieties are shown in Table XXXIX.

During the 8-year period, 1912 to 1919, inclusive, the White Russian variety averaged 51.7 bushels per acre. This was higher than any of the other varieties grown during the period. The average yield of White Russian during the 5-year period, 1915 to 1919, inclusive, was 57.9 bushels per acre. A panicle and spikelets of the White Russian oat are shown in figure 16. During this same period the Silvermine variety averaged 58.2 bushels per acre. Panicles and spikelets of the Silvermine and Swedish Select varieties are shown in figure 17. The Sixty-Day variety averaged only 47.3 bushels. These yields are shown graphically in figure 18.

Early oats do not appear to be well adapted to the irrigated land at Newell.

The Sixty-Day oat is a small, short-strawed, yellow variety which matures very early. It matures too early to make the best use of the irrigation water supply, but is well adapted to the dry land. Because of its slow maturity the White Russian, a late side or horse-mane oat, is able to utilize the soil moisture and to occupy more of the growing season. Of the midseason varieties, Silvermine has given the highest yields and is perhaps the best variety for the irrigated lands. Several other midseason varieties, such as Canadian and Swedish Select, produce large, plump grains, but the average yields have been less than White Russian and Silvermine.



FIG. 16.—Panicle and spikelets of the White Russian oat.



FIG. 17.—Panicles and spikelets of oats, two varieties; 1, Silvermine; 2, Swedish Select.

TABLE XXXIX.—Yields of the oat varieties grown on irrigated land on the Belle Fourche Experiment Farm, 1912 to 1917, inclusive.

Group and variety.	C. I. No.	Yields per acre (bushels).									
		1912	1913	1914	1915	1916	1917	1918	1919	Average 1912 to 1919.	1915 to 1919.
Early:											
Sixty-Day.....	165	25.0	47.1	32.5	34.0	28.8	51.5	75.0	47.2	42.6	47.3
Kherson.....	459	30.4	.....	.....	.....	.....	.....	.....	.....	.....	.....
Albion (Iowa No. 103).....	729	.....	.....	.....	.....	20.2	.....	.....	.....	.....	.....
Richland (Iowa No. 105).....	787	.....	.....	.....	.....	18.1	.....	.....	.....	.....	.....
Midseason:											
Swedish Select.....	134	35.2	33.0	41.6	46.5	39.6	54.6	77.9	52.1	47.2	54.1
Canadian.....	444	31.2	39.3	42.4	44.7	25.9	65.8	85.2	50.5	48.1	54.4
Lincoln.....	781	.....	.....	.....	50.7	36.1	52.8	74.2	.....	.....	.....
Silvermine.....	782	.....	.....	.....	52.3	41.6	61.1	79.2	56.8	.....	58.2
Pete Edwards ^a	778	.....	.....	50.7	51.8	37.4	57.8	73.7	61.0	.....	56.3
Abundance.....	780	.....	.....	.....	.....	35.3	57.0	72.7	.....	.....	.....
Great Dane.....	.....	.....	.....	32.8	.....	.....	.....	.....	.....	.....	.....
New White Danish.....	.....	.....	.....	.....	.....	34.8	.....	.....	.....	.....	.....
Late:											
Mammoth Cluster.....	779	.....	.....	43.7	.....	24.7	.....	.....	.....	.....	.....
White Russian.....	551	41.4	33.7	48.6	52.8	42.1	56.2	75.3	63.0	51.7	57.9
White Tartarian.....	300	46.8	.....	.....	.....	.....	.....	.....	.....	.....	.....

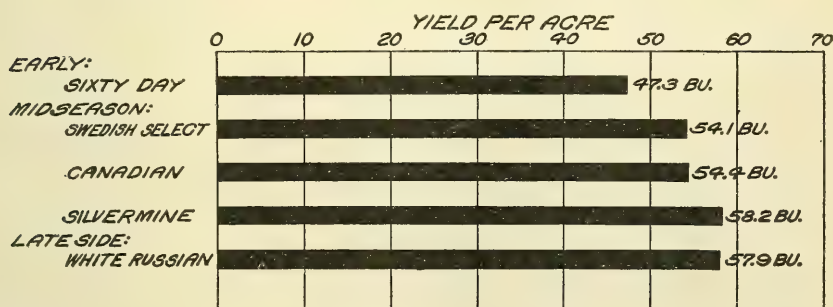
^a A local variety of the Swedish Select type.

FIG. 18.—Diagram showing the average yields, in bushels per acre, of five varieties of oats on irrigated land at the Belle Fourche Experiment Farm for the 5-year period from 1915 to 1919, inclusive.

TABLE XL.—Average agronomic data of oat varieties grown on irrigated land on the Belle Fourche Experiment Farm, 1912 to 1917, inclusive, and in 1919.

Group and variety.	C. I. No.	Date of—		Height.	Weight per bushel.	Yields per acre.	
		Heading.	Maturity.			Grain.	Straw.
Early yellow:							
Sixty-Day.....	165	July 4	July 26	Inches. 26	Pounds. 32.7	Bushels. 38.0	Pounds. 1,035
Midseason white:							
Canadian.....	444	July 13	Aug. 2	33	36.3	42.7	1,498
Swedish Select.....	134	July 14	Aug. 5	31	34.9	42.8	1,408
Late side:							
White Russian.....	551	July 19	Aug. 13	33	33.7	48.3	1,793

Table XL shows the average dates of heading and maturity, height, weight per bushel, and yields of grain and straw of the four oat

varieties grown from 1912 to 1919, inclusive. The results for 1918 are not included. During this period the Sixty-Day variety matured 7 days earlier than Canadian, 10 days earlier than Swedish Select, and 18 days earlier than White Russian. The Sixty-Day oat was also shorter and had a lower weight per bushel than the other varieties.

RATE-OF-SEEDING EXPERIMENTS.

Silvermine oats were grown in rate-of-seeding experiments at Newell in 1918 and 1919. The seed was sown at four different rates, viz, 6, 8, 10, and 12 pecks per acre, in triplicated fiftieth-acre plats. The yields are shown in Table XLI.

TABLE XLI.—*Yields of Silvermine oats grown in rate-of-seeding experiments on irrigated land on the Belle Fourche Experiment Farm in 1918 and 1919.*

Rate of seeding per acre.	Yields per acre (bushels).		
	1918	1919	Average.
6 pecks.....	77.1	58.5	67.8
8 pecks.....	79.9	61.7	70.8
10 pecks.....	73.2	64.6	68.9
12 pecks.....	69.6	63.3	66.5

The 8-peck seeding gave the highest yield in 1918 and the 10-peck seeding in 1919. The yields were good and quite uniform in both seasons. The average yield from the 8-peck seeding was 70.8 bushels and from the 10-peck seeding 68.9 bushels per acre, with the 6-peck and 12-peck seedings yielding slightly less. At Newell 8 pecks per acre seems to be sufficient seed for Silvermine oats, but for greater certainty of crop the seeding of 10 pecks per acre would be desirable.

EXPERIMENTS WITH BARLEY.

VARIETAL EXPERIMENTS.

Eleven varieties of barley have been grown on irrigated land at Newell. None of these were grown during all of the eight years from 1912 to 1919, but four varieties were grown continuously for six years. The yields in general were not very large, but good crops were harvested in 1915, 1917, and 1918. The yields are shown in Table XLII.

The Chevalier II variety produced the highest average yield, 38.5 bushels per acre, from 1914 to 1919, inclusive. This variety also gave the highest yield during the three years 1917 to 1919. A head of Chevalier II barley is shown in figure 19. The Trebi variety yielded nearly as well. The former is a late 2-rowed barley which is able to develop fully in the presence of sufficient soil moisture.

The Hannchen variety, which was grown during four of the eight years from 1912 to 1919, is slightly earlier than the Chevalier II, and it probably will yield nearly as well. The Chevalier II is a selected strain of the Chevalier, developed at the Svalof Experiment Station in Sweden. A field of Chevalier being irrigated is shown in figure 20.

The Trebi is the latest and also the highest yielding of the 6-rowed varieties grown. This variety is also well adapted to the irrigated sections of Idaho. The Coast variety yielded an average of 43 bushels per acre. This variety has strong persistent awns, which make it harder to thrash and less desirable for feeding than the other varieties. The grain has a bluish appearance. The different strains of Manchuria do not seem to be well adapted to the irrigated land at Newell, as the yields are less than from the other varieties. The Manchuria barley is the one most commonly grown throughout the Dakotas and Minnesota.

The Himalaya (or Guy Mayle) is a blue hull-less variety, having awned spikes. When the amount of hull on the hulled varieties is considered the Himalaya has yielded about as well as any of the 6-rowed

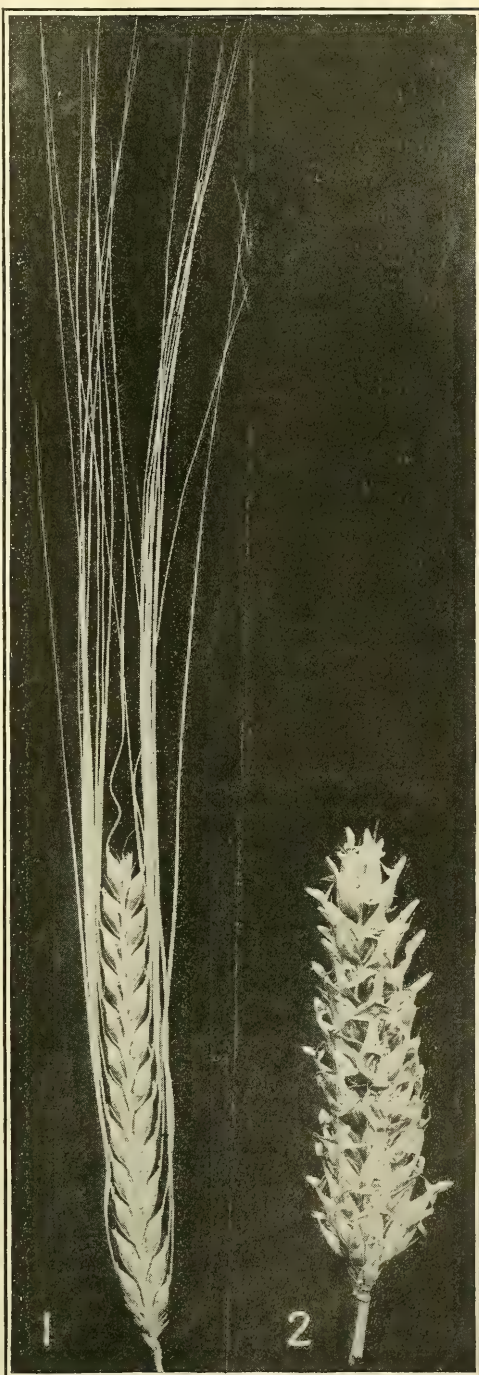


FIG. 19.—Heads of two varieties of barley: 1, Chevalier; 2, Nepal.

varieties with the exception of Trebi. The Nepal (White Hull-less) variety has not given good yields, its only advantage appearing to be the lack of awns. A head of Nepal barley is shown in figure 19.



FIG. 20.—Irrigating a field of Chevalier barley on the Belle Fourche Experiment Farm.

TABLE XLII.—Yields of varieties of barley grown on irrigated land on the Belle Fourche Experiment Farm, 1912 to 1919, inclusive.

Group and variety.	C. I. No.	Yields per acre (bushels).									Average.	
		1912	1913	1914	1915	1916	1917	1918	1919		1914 to 1919	1917 to 1919
Six-rowed, hulled:												
Coast.....	690	.....	.....	.....	23.0	15.2	37.9	65.6	25.4	.....	43.0	
Manchuria (Wis. No. 13).....	905	.....	25.8	21.8	20.9	14.7	23.9	66.7	17.7	27.6	36.1	
Manchuria (Minn. No. 6).....	638	16.9	.....	.....	.....	.....	.....	.....	.....	.....	.....	
Manchuria (Minn. No. 105).....	354	.....	23.5	17.8	.....	.....	.....	.....	.....	.....	.....	
Odessa.....	182	17.4	.....	.....	.....	.....	.....	.....	.....	.....	.....	
Trebi.....	936	.....	.....	.....	.....	.....	38.0	75.9	28.8	.....	47.6	
Two-rowed, hulled:												
Chevalier.....	1162	.....	.....	26.8	37.2	23.2	.....	.....	.....	.....	.....	
Chevalier II.....	530	13.0	.....	23.0	39.2	23.9	38.5	74.3	32.0	38.5	48.3	
Hannchen.....	531	19.8	32.9	15.0	.....	25.1	40.7	.....	.....	.....	.....	
Six-rowed, naked:												
Himalaya (Guy Mayle).....	620	.....	.....	26.6	23.4	17.5	23.7	62.7	17.5	28.6	34.6	
Six-rowed hooded, naked:												
Nepal (White Hull-less).....	595	9.1	.....	19.2	20.4	14.9	22.3	51.6	18.4	24.5	30.8	

Table XLIII shows the average dates of heading and maturity, height, weight per bushel, and yields of grain and straw of four varieties of barley grown from 1914 to 1917, inclusive, and 1919. The average yields of these four varieties are also shown in figure 21.

The Chevalier II is taller, later, and produces much higher yields than the other varieties.

TABLE XLIII.—Average agronomic data of four varieties of barley grown on irrigated land on the Belle Fourche Experiment Farm, 1914 to 1917, inclusive, and in 1919.

Group and variety.	C. I. No.	Date of—		Height.	Weight per bushel.	Yields per acre.	
		Head- ing. ^a	Matur- ity. ^a			Grain.	Straw.
Six-rowed, hulled:				Inches.	Pounds.	Bushels.	Pounds.
Manchuria.....	905	July 10	Aug. 7	26	47.7	19.8	1,145
Two-rowed, hulled:							
Chevalier II.....	530	July 17	Aug. 17	27	50.1	31.3	1,472
Six-rowed, naked:							
Himalaya.....	620	July 9	Aug. 4	23	60.0	21.7	995
Six-rowed, hooded, naked:							
Nepal.....	595	July 10	Aug. 6	25	60.3	19.0	917

^a Average for four years, 1915, 1916, 1917, and 1919.

NURSERY EXPERIMENTS.

About 35 varieties of barley, representing a wide range of types, were grown in 17-foot rows under irrigation in 1917 and 1919. The

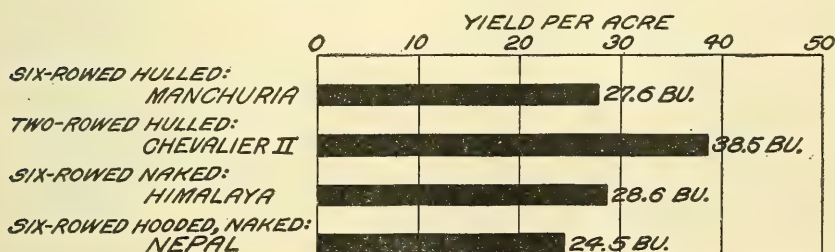


FIG. 21.—Diagram showing the average yields, in bushels per acre, of four varieties of barley on irrigated land at the Belle Fourche Experiment Farm for the 6-year period from 1914 to 1919, inclusive.

object was to observe the behavior of the varieties under irrigated conditions. In general the late varieties produced the highest yields, which was in accordance with the results from the plat experiments. Further tests would be necessary to determine definitely the yields in comparison with the varieties grown in plats.

EXPERIMENTS WITH MINOR CEREALS.

SPRING EMMER.

One variety of spring emmer, Vernal (White Spring), has been grown under irrigation each year in comparison with either the barley or oat varieties. The soil and preparation have been the same each year for both oats and barley, and usually spring wheat also, so that these crops can be compared directly with the emmer.

The yields of emmer have ranged from 24.5 bushels in 1912 to 88 bushels per acre in 1918, with an average of 48.1 bushels of 32 pounds each per acre. The yields of Vernal emmer in pounds per acre for the five years from 1915 to 1919, inclusive, are shown in Table XLVIII (p. 65), which gives a comparison of the yields of the grain crops. During this period Vernal emmer yielded an average of 1,911 pounds per acre, Kubanka wheat 1,667 pounds, Chevalier II barley 2,016 pounds, and White Russian oats 1,852 pounds. Emmer is used as a feed crop and thus competes only with barley and oats. The results obtained at Newell on irrigated land show that barley is a more profitable feed crop than emmer, and it also has a higher feeding value.

WINTER EMMER AND SPELT.

One variety of emmer (Buffum Black Winter) and one of spelt (Brown Winter) were grown on irrigated land along with the winter-wheat varieties in 1916 and 1917. Single plats of each were sown. During the winter of 1915-16 a part of these crops was winterkilled, so that the stands were thin. The emmer yielded at the rate of 425 pounds and the spelt 100 pounds per acre. Kharkof winter wheat in the same series yielded 678 pounds per acre. The winter of 1916-17 was more severe, and both the emmer and spelt were almost entirely winterkilled. The plats were disked to destroy weeds. Kharkof winter wheat in the same series yielded 1,394 pounds per acre. Neither winter emmer nor winter spelt are sufficiently hardy to be safely grown in western South Dakota. They yield less and are also less valuable than winter wheat.

RYE.

Two varieties of winter rye were grown in the experiments along with the winter-wheat varieties on irrigated land from 1915 to 1918, inclusive. The rye was sown at the rate of 5 pecks per acre. Winter rye is more hardy and consequently more certain than winter wheat. The yields obtained from the rye were less in pounds per acre than the wheat yields in all years. The average acre yield of the Swedish rye during the four years was 23.6 bushels of 56 pounds each, while Kharkof wheat during the same period averaged 32.6 bushels of 60 pounds each.

The North Dakota No. 959 rye averaged only 0.9 bushel per acre less than the Swedish. This was partly due to the former being on poorer land in 1915. The North Dakota No. 959 rye is probably the hardier, but both are sufficiently hardy for the climate at Newell.

The yields of rye in comparison with Kharkof winter wheat are shown in Table XLIV.

TABLE XLIV.—*Comparison of the yields of two varieties of winter rye and of Kharkof winter wheat on irrigated land on the Belle Fourche Experiment Farm, 1915 to 1918, inclusive.*

[Yields of wheat computed at 60 pounds per bushel, rye at 56 pounds per bushel.]

Crop and variety.	C. I. No.	Yields per acre (bushels).				
		1915	1916	1917	1918	Average.
Rye:						
Swedish (Minn. No. 2).....	137	44.6	10.8	21.3	17.5	23.6
N. Dak. No. 959.....	175	^a 38.8	11.7	25.4	14.8	22.7
Winter wheat:						
Kharkof.....	1583	66.3	11.3	29.5	23.4	32.6

^a One plat only.

BUCKWHEAT.

Buckwheat was grown only in 1916 and 1917 on irrigated land. In 1916 a plat of about 0.15 acre was sown to buckwheat on May 31 at the rate of 6 pecks per acre. The seed was of the Japanese type obtained locally. The plants were in full bloom during the hottest weather and many of the flowers were blasted. Although considerable plant growth was made, the plat yielded at the rate of only 21.1 bushels per acre. In 1917 a plat containing about 0.9 acre was sown to buckwheat on June 16. The land was sloping and the buckwheat was injured by the soil washing at the first irrigation. The land also contained a considerable growth of volunteer barley, alfalfa, and weeds, which the buckwheat failed to check. The yield was 12.7 bushels per acre. Buckwheat is not as productive as other grain crops at Newell.

PROSO.

Proso was grown only in 1918 and 1919 on irrigated land. It is not well suited to irrigated conditions, and many other late sown crops doubtless are more profitable. The yields were not large during either season, and in 1919 the crop was damaged considerably by birds. Four varieties of proso were grown under irrigation, the yields of which are shown in Table XLV.

TABLE XLV.—*Yields of four varieties of proso grown on irrigated land on the Belle Fourche Experiment Farm in 1918 and 1919.*

Variety.	C. I. No.	Yields per acre (bushels).		
		1918	1919 ^a	Average.
White Ural.....	4	21.4	5.9	13.7
Hansen.....	179	15.5	5.7	10.6
Red Russian.....	61	27.1	16.5	21.8
Black Voronezh.....	27	25.9	11.6	18.8

^a Damaged by birds in 1919.

The Red Russian variety gave an average yield of 21.8 bushels per acre, while the next highest variety, Black Voronezh, yielded 18.8 bushels per acre. The Hansen variety gave the lowest yields during both seasons.

EXPERIMENTS WITH GRAIN MIXTURES.

WHEAT, OATS, AND BARLEY MIXTURES.

Mixtures of grains, chiefly of barley and oats, have occasionally been grown by farmers. The mixtures are often referred to as "succotash." An experiment to determine the value of this practice of growing mixed grains on irrigated land was begun at Newell in 1915 and continued for three years, after which further experiments seemed to be unnecessary.

The varieties selected were the Chevalier II barley, Swedish Select oats, and Kubanka wheat. From past observations these varieties were known to mature at practically the same time if sown on the same date. This proved to be the case in these experiments. These varieties were well adapted to growing under irrigation, were not easily shattered at maturity, and were not subject to severe rust injury.

In the plats sown to the single grains the barley was sown at the rate of 6 pecks, the oats at 10 pecks, and the wheat at 5 pecks per acre. The grains were sown with a disk drill which, when set to sow the above quantities, was found from calibration tests to sow the proper measured quantity regardless of bushel weight. In preparing the mixtures the weights per bushel of the grain were first determined. The mixtures of two grains contained seed of each to sow half of the quantity of seed used for each grain when sown alone. The mixture of barley, oats, and wheat contained one-third of the quantity of seed used for each grain sown alone. The drill was calibrated for each mixture so as to sow the proper quantities of mixed grain. The proportions of each grain in the thrashed crop were not determined.

The yields of the mixed grains, the grains grown alone, and the average yields of the two or three grains grown alone are shown in Table XLVI.

Good yields of all grains were obtained in 1915 and 1917, but the yields in 1916 were reduced somewhat by soil blowing and rust. In 1915 about 10 per cent of the grain from the grains and mixtures was shattered by hail while standing in the shock. The barley had been thrashed before the hail, however, so the yield shown for 1915 has been reduced 10 per cent to make it comparable with the other grains.

TABLE XLVI.—*Yields of wheat, oats, and barley, separately and mixtures of these crops, grown on irrigated land on the Belle Fourche Experiment Farm, 1915 to 1917, inclusive.*

Crop and mixture.	Yields per acre (pounds).			
	1915	1916	1917	Average.
Barley.....	1,830	1,108	2,516	1,818
Oats.....	1,825	1,300	2,325	1,816
Wheat.....	1,641	1,083	2,391	1,705
Barley and oats.....	1,950	1,300	2,516	1,922
Barley and wheat.....	1,775	1,083	2,300	1,719
Oats and wheat.....	1,750	1,333	2,225	1,769
Barley, oats, and wheat.....	1,930	1,283	2,108	1,774
Averages of crops grown alone:				
Barley and oats.....	1,828	1,204	2,420	1,817
Barley and wheat.....	1,735	1,095	2,453	1,761
Oats and wheat.....	1,733	1,191	2,358	1,760
Barley, oats, and wheat.....	1,765	1,164	2,411	1,780

In 1915 all of the mixtures and in 1916 all of the mixtures except the barley and wheat showed higher yields than the averages of the crops grown alone. In 1917 the barley and wheat, oats and wheat, and the barley, oats, and wheat mixtures yielded less than the averages in the grains sown alone. The 3-year average yields show very little advantage in growing the grain mixtures. The barley and oats mixture yielded 105 pounds per acre more than the average of the two crops grown alone, but the other three mixtures yielded nearly the same as the averages of the same grains grown alone. Under the conditions of the experiment the growing of grain mixtures would not be advisable. If the varieties of the different crops had very different habits or periods of growth, increased yields from mixtures might be expected, but this would be offset by the difficulties and losses in harvesting.

WHEAT AND FLAX MIXTURES.

The experiments with mixtures of wheat and flax were begun in 1916. After the crops had emerged the severe soil blowing early in May destroyed nearly all of the flax plants, both in the mixtures and where sown alone. Most of the wheat plants survived, but the mixture experiment was of no value. The mixtures of wheat and flax were again sown in 1917 and 1918. The flax, Damont, C. I. No. 3, was sown at the rate of 15 pounds per acre, whether mixed with wheat or sown alone.

The wheat, Marquis, C. I. No. 3641, was sown at the rates of 37 pounds and 75 pounds per acre alone and mixed with flax. The almost total absence of weeds from the plats made the experiment of less value, because the object of the mixture of wheat and flax is to overcome or replace weeds. The relative quantities of wheat and flax produced in the mixtures were determined only in 1917.

The yields of the wheat, flax, and the mixtures of both are shown in Table XLVII.

TABLE XLVII.—*Yields of flax and wheat separately and mixtures of these crops grown on irrigated land on the Belle Fourche Experiment Farm in 1917 and 1918.*

Crops.	Rates of seeding and yields per acre (pounds).			
	Seeding.	Yields.		
		1917	1918	Average.
Flax.....	15	941	867	904
Mixture ^{flax} { _{wheat}	15 37	1,150	1,408	1,279
Wheat.....	37	1,100	1,308	1,204
Mixture ^{flax} { _{wheat}	15 75	1,425	1,467	1,446
Wheat.....	75	1,300	1,442	1,371

Larger total yields of wheat and flax were obtained from the mixtures than from either crop grown alone. Wheat predominated in the mixtures. The value of the practice of growing the mixture of wheat and flax will depend on the relative prices and yields of the two crops. The cost of separating the thrashed crop must also be considered. It was necessary to let the wheat stand for some time after it was ripe before the flax could be harvested, and it was also rather difficult to thrash the flaxseed without cracking many of the wheat grains.

COMPARISON OF GRAIN CROPS.

In 1912, 1913, and 1914 the only small grains grown in the cereal experiments under irrigation were spring varieties of wheat, oats, barley, and emmer. In 1915 and since several additional grains have been grown. The annual and average yields of the leading varieties of each of the grains grown in 1915 and later are shown in Table XLVIII.

Winter wheat and winter rye were grown during only four of the five years from 1915 to 1919, inclusive, while winter spelt, winter emmer, proso, and buckwheat were grown only two years each. In terms of pounds of grain per acre, winter wheat gave the highest yield in 1915, oats in 1916 and 1919, spring wheat in 1917, and barley in 1918. Chevalier II barley has outyielded all other grains during both the 4-year and the 5-year periods, for which the average yields are shown in Table XLVIII. Vernal spring emmer and White Russian oats gave the next highest yields of grain. Winter emmer, win-

ter spelt, proso, and buckwheat produced rather low yields and are not well adapted to growing at Newell under irrigation, and none of these four crops except proso are at all adapted to the dry-land conditions there.

TABLE XLVIII.—Yields of the leading varieties of different grain crops grown on irrigated land on the Belle Fourche Experiment Farm, 1915 to 1919, inclusive.

Group and variety.	C. I. No.	Yields per acre (pounds).						Average.	
		1915	1916	1917	1918	1919		1915 to 1918	1915 to 1919
Kharkof winter wheat.....	1583	^a 3,976	678	1,770	1,394	-----	-----	1,955	-----
Swedish (Minn. No. 2) winter rye..	137	^a 2,496	655	1,192	980	-----	-----	1,331	-----
Buffum Black Winter emmer.....	3331	-----	425	0	-----	-----	-----	-----	-----
Vernal spring emmer.....	1524	1,855	1,141	1,845	2,816	1,900	-----	1,914	1,911
Kubanka durum spring wheat.....	1440	1,320	1,248	1,968	2,016	1,782	-----	1,638	1,667
Brown Winter spelt.....	-----	-----	100	0	-----	-----	-----	-----	-----
Chevalier II barley.....	530	1,881	1,150	1,848	3,567	1,536	-----	2,112	2,016
White Russian oats.....	551	1,690	1,347	1,798	2,410	2,016	-----	1,811	1,852
Red Russian proso.....	61	-----	-----	-----	1,518	924	-----	-----	-----
Japanese buckwheat.....	-----	-----	1,042	609	-----	-----	-----	-----	-----

^a Not comparable with spring grains; grown on better soil.

EXPERIMENTS WITH FLAX.

Flax has been a fairly successful crop on irrigated land. It also is an excellent nurse crop for alfalfa. The yields obtained at Newell

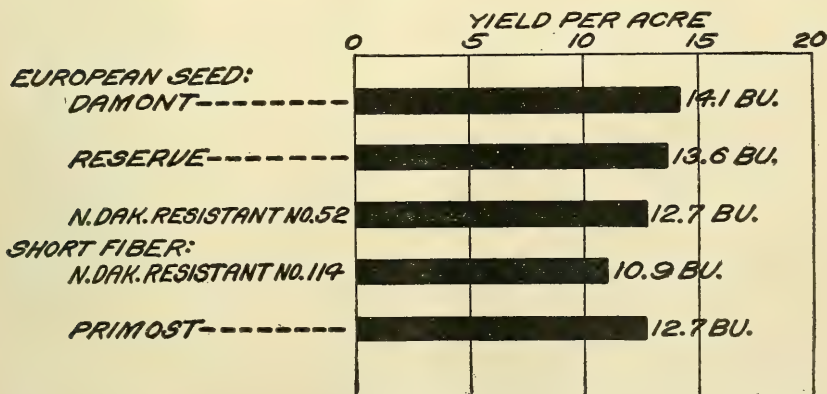


FIG. 22.—Diagram showing the average yields, in bushels per acre, of the leading varieties of flax on irrigated land at the Belle Fourche Experiment Farm for the 6-year period from 1914 to 1919, inclusive.

were fairly good except in 1913 when the flax was grown on poor land. Some infection of wilt and canker has been observed in the experiments, but the injury usually was very slight. A spot about 8

feet in diameter, mostly in a plat of North Dakota Resistant No. 52, was made almost bare by wilt in 1916. The same land had produced flax in 1914.

VARIETAL EXPERIMENTS.

Varietal experiments with flax on irrigated land were begun in 1912. Ten varieties have been grown, three of them during each of the eight years. Five varieties were grown during the six years from 1914 to 1919, inclusive. All varieties were of the blue-flowered, brown-seeded type. The yields of the flax varieties are shown in Table XLIX. The average yields of five varieties are also shown graphically in figure 22.

TABLE XLIX.—*Yields of flax varieties grown on irrigated land on the Belle Fourche Experiment Farm, 1912 to 1919, inclusive.*

Group and variety.	C. I. No.	Yields per acre (bushels).									
		1912	1913	1914	1915	1916	1917	1918	1919	Average.	
										1912 to 1919	1914 to 1919
European seed:											
Russian (N. Dak. No. 608).....	1	-----	-----	3.7	-----	-----	-----	-----	-----	-----	-----
Damont (N. Dak. No. 1215).....	3	-----	-----	11.8	14.5	10.7	15.1	21.7	10.7	-----	14.1
Frontier (Russian).....	17	10.1	-----	-----	-----	-----	-----	-----	-----	-----	-----
Reserve (Russian).....	19	12.5	5.3	10.0	14.1	12.7	13.6	19.1	11.9	12.4	13.6
N. Dak. Resistant No. 52.....	8	11.9	4.8	5.8	13.6	10.7	12.9	20.8	12.2	11.6	12.7
Common.....		11.3	-----	-----	-----	-----	-----	-----	-----	-----	-----
Short fiber:											
N. Dak. Resistant No. 114.....	13	-----	-----	11.1	12.4	6.5	11.4	15.5	8.6	-----	10.9
Primost (Minn. No. 25).....	12	11.1	5.3	11.6	12.9	9.0	10.0	20.5	12.2	11.6	12.7
Turkish:											
Turkish.....	7	-----	4.4	1.5	-----	-----	-----	-----	-----	-----	-----
Smyrna.....	30	-----	-----	-----	6.0	4.1	-----	-----	-----	-----	-----

The Damont and Reserve varieties have produced the highest yields, the former averaging 14.1 bushels and the latter 13.6 bushels per acre. Both of these varieties are rather tall, with medium-large seeds. The Primost and North Dakota Resistant No. 114 varieties belonging to the short-fiber group have short stems and small, dark-brown seeds. Neither of the wilt-resistant varieties grown produced the highest yields, because of the almost total absence of wilt.

The two varieties of the Turkish group, Turkish and Smyrna, which were grown in the experiments produced relatively low yields and were almost too short to harvest with the binder.

Table L shows the average dates of heading and maturity, height, weight per bushel, and yields of seed and straw of three varieties of flax grown from 1914 to 1919, inclusive. The Damont was one and two days, respectively, later than the North Dakota Resistant No. 52 and Primost varieties. The average height apparently is the same

for all three varieties, but in general Primost is somewhat shorter than the other two. The weight per bushel of the three varieties is about the same.

TABLE L.—Average agronomic data of three varieties of flax grown on irrigated land on the Belle Fourche Experiment Farm, 1914 to 1917, inclusive, and in 1919.

Group and variety.	C. I. No.	Date of—		Height. ^a	Weight per bushel.	Yields per acre.	
		Full bloom. ^a	Maturity.			Seed.	Straw.
European seed:				<i>Inches.</i>	<i>Pounds.</i>	<i>Bushels.</i>	<i>Pounds.</i>
Damont.....	3	July 13	Aug. 6	20	54.3	12.6	1,027
N. Dak. Resistant No. 52.....	8	July 11	Aug. 5	20	54.5	11.0	949
Short fiber:							
Primost (Minn. No. 25).....	12	July 10	Aug. 4	20	54.3	11.1	891

^a Average for 1915, 1916, 1917, and 1919.

NURSERY EXPERIMENTS.

Several varieties of flax were grown in 17-foot rows under irrigation for preliminary testing during the 5-year period, 1915 to 1919. None of these yielded as well as varieties already being grown in plats. Some selections of Smyrna flax, C. I. No. 30, were made in 1915 to increase the height of the variety. Strains of the parent type 1 to 2 inches higher than the parent variety were isolated, but the yields were not sufficiently large to justify their being increased.

RATE-OF-SEEDING EXPERIMENTS.

Rate-of-seeding experiments with Damont flax on irrigated land were begun in 1916 in single fiftieth-acre plats. In 1917, 1918, and 1919 the experiment was triplicated. Good yields were obtained in all years. The flax was sown at three different rates during each of four years, with an additional rate in 1918. The yields are shown in Table LI.

TABLE LI.—Yields of Damont flax grown in rate-of-seeding experiments on irrigated land on the Belle Fourche Experiment Farm, 1916 to 1919, inclusive.

Rate of seeding per acre.	Yields per acre (bushels).				
	1916	1917	1918	1919	Average.
15 pounds.....	10.7	13.8	17.7	10.7	13.2
22½ pounds.....	.....	.....	21.1	.....	.....
30 pounds.....	10.2	15.2	23.7	13.7	15.7
45 pounds.....	11.0	14.2	23.4	13.8	15.6

The highest average yield was obtained from the seeding of 30 pounds per acre. The 45-pound rate yielded 0.1 bushel per acre

less, while the 15-pound rate yielded an average of 2.5 bushels per acre less than the 30-pound rate. The best rate of seeding for irrigated flax on a clean, well-prepared seed bed apparently is about 30 pounds per acre, but under less favorable conditions more seed might be desirable.

DATE-OF-SEEDING EXPERIMENTS.

Damont flax was grown in date-of-seeding experiments from 1916 to 1919, inclusive. Because of seasonal irregularities, especially spring rains, it was not possible to sow the flax on the exact dates planned. Seedings were made on three dates in 1916 and on five dates during each of the other three years. The experiment usually was conducted in duplicate. Good yields were obtained each year. The yields are shown in Table LII.

TABLE LII.—*Yields of Damont flax grown in date-of-seeding experiments on irrigated land on the Belle Fourche Experiment Farm, 1916 to 1919, inclusive.*

Date seeded.	Yields per acre (bushels).					
	1916	1917	1918	1919	Average.	
					1916 to 1919	1917 to 1919
April 15 to 23.....	8.4	.....	23.7	13.4	.....	.....
May 1 to 8.....	.....	16.9	24.9	13.0	.....	18.3
May 15 to 26.....	11.6	12.3	23.2	12.5	14.9	16.0
June 1 to 10.....	12.5	14.2	20.4	12.1	14.8	15.6
June 15 to 20.....	.....	10.7	14.6	12.1	.....	12.5
June 30.....	.....	5.3	.....	.....	.....	.....

The highest yield was produced by the latest date of seeding in 1916, the earliest date in 1917 and 1919, and the second earliest date in 1918. The results are somewhat inconclusive, but in general early seeding is somewhat more favorable for flax. The highest average yield for the 3-year period from 1917 to 1919, inclusive, was obtained from the seeding of May 1 to 8. The later dates of seeding produced progressively lower yields. Fair yields of flax from late seeding may be obtained in some years. The seeding of June 30, in 1917, was fully matured, but yielded only 5.3 bushels per acre. The flax was damaged considerably in irrigating, however. When possible, flax probably should be sown on irrigated land at Newell not later than the first week in May.

LATE IRRIGATION EXPERIMENT.

Irrigation of flax after it is in full bloom has been supposed to be detrimental, as it causes a renewed or second blooming and delays the maturity of the seed. In 1916, a single twentieth-acre plat of

Primost flax, C. I. No. 12, was given a late irrigation on July 25, while an adjoining plat of the same size was not irrigated. Both had been irrigated 15 days previous. When this late irrigation was applied the flax had practically completed blooming and most of the bolls were formed.

The late irrigation caused considerable late blooming, perhaps a third more than occurred on the check plat. Maturity was delayed only three days as compared with the check plat not irrigated. The plat receiving the late irrigation yielded at the rate of 15.7 bushels per acre, while the adjoining plat yielded only 13.3 bushels. The season was dry and warm, so that the increased soil moisture proved to be beneficial. This might not always occur, but it indicates that flax may be irrigated after blooming in most seasons without injury.

TILLAGE EXPERIMENTS.

Most of the spring grains under irrigation were sown on disked corn ground. The soil was a heavy clay and usually quite compact at the time of seeding, even after being double disked and harrowed. An experiment in tillage treatment of corn ground in preparation for spring grain was conducted during the 1915-16 crop year. The plats were all one-fiftieth of an acre in size.

Thirteen plats were plowed in the fall to a depth of 7 or 8 inches, 13 were subsoiled about 12 inches deep in the fall, while the 13 remaining were not touched until spring. Plowing was done with a disk plow. The subsoiler was run twice between the rows of corn stubble on unplowed land. In the spring all plats were double disked and floated alike and all subsequent treatment of the plats was the same.

The plats were sown to Kubanka wheat, Swedish Select oats, Chevalier barley, and Primost flax. Three plats each of wheat, barley, and flax and four plats of oats were sown on ground representing the three different tillage treatments, making a total of 39 plats in the experiment. Because of soil blowing, rust, and the presence of considerable wild oats, the yields obtained were not large. The yields from the experiment are shown in Table LIII.

TABLE LIII.—Yields of spring wheat, oats, barley, and flax grown following a corn crop in a tillage experiment on irrigated land on the Belle Fourche Experiment Farm in 1916.

Fall tillage.	Yields per acre (bushels).			
	Kubanka wheat.	Swedish Select oats.	Chevalier barley.	Primost flax.
Plowed.....	16.7	40.6	18.5	9.7
Subsoiled.....	16.3	39.8	18.1	9.4
None.....	17.8	41.1	19.6	10.2

The differences in yields obtained from the three tillage treatments are rather small. However, the results were the same for all four crops. In all cases the plats receiving no tillage treatment in the fall gave the highest yields, the plowed plats gave the next highest, and the subsoiled plats the lowest yields. Under the conditions of the experiment, plowing or subsoiling of corn ground in preparation for spring grain proved to be harmful rather than a benefit. The results are not entirely conclusive, because of having been obtained for only one year.

SUMMARY.

The experiments here reported were conducted on dry land during the 12 years from 1908 to 1919, inclusive, and on irrigated land during the 8 years from 1912 to 1919, inclusive.

The Belle Fourche Experiment Farm is located in the western part of South Dakota, about 30 miles northeast of the Black Hills. The results obtained are applicable to western South Dakota and adjoining sections in northeastern Wyoming, southeastern Montana, and southwestern North Dakota.

The soil on which these experiments were conducted is a heavy, impervious clay, or gumbo, known as Pierre clay.

The average annual precipitation for the 12 years was 14.31 inches and the seasonal precipitation, March to July, inclusive, averaged 8.57 inches. The annual precipitation ranged from 6.64 inches in 1911 to 21.02 inches in 1915. The seasonal precipitation is an important factor influencing the yields of grain. The average yields of the best varieties of wheat, oats, and barley on dry land have been fairly satisfactory, but partial or complete failures in some years have made grain growing uncertain. Other small grain crops are not as successful as wheat, oats, and barley.

Durum wheats have given higher yields than common spring wheat. Kubanka is the highest yielding variety. Marquis has given the highest yields of any of the common spring-wheat varieties. Kubanka wheat should be sown at the rate of about 4 pecks per acre on an ordinary seed bed. The wheat should be sown as early as weather and soil conditions permit.

The hard red winter wheats, Turkey and Kharkof, have produced the highest yields of the winter varieties. These two varieties are of equal value and are apparently identical.

Seeding at the rate of 4 pecks per acre has given the highest net yields on fallowed land. The best date of seeding for winter wheat is about September 16. Early-sown wheat does not survive the winter better than late-sown wheat.

Winter wheat has produced higher average yields than spring wheat, but is rather uncertain on account of winterkilling and soil blowing.

Spring emmer has not yielded as well as the best varieties of oats and barley. It is not resistant to extreme drought. Winter rye has yielded less than winter wheat, but it is hardier and more certain. Winter emmer and winter spelt are not hardy enough to be grown successfully in western South Dakota.

The early varieties of oats, Kherson and Sixty-Day, have given the highest yields. These varieties should be sown at the rate of 6 pecks per acre.

White Smyrna and Hannchen are the highest yielding varieties of barley on the dry land. The barley should be sown at the rate of 4 to 6 pecks per acre.

Red Russian proso has given the highest yields in plat experiments, and the Turghai in nursery experiments. Seeding proso in ordinary drill rows at the rate of 25 to 30 pounds per acre has given the highest yields.

Grain sorghums mature too late and require too much warm weather to be successfully grown at Newell. Manchu Brown kaoliang is the most certain of the grain sorghums yet grown there.

Damont (Select Russian) flax has given the highest yields. Reserve (N. Dak. No. 155) is the next best variety. The best rate of seeding for flax on dry land is about 2 pecks per acre. Flax should be sown before May 15.

The following varieties of grain are recommended for growing on dry land:

<i>Spring wheat</i> .—Kubanka, Marquis.	<i>Barley</i> .—White Smyrna, Hannchen.
<i>Winter wheat</i> .—Turkey or Kharkof.	<i>Proso</i> .—Red Russian, Turghai.
<i>Oats</i> .—Kherson or Sixty-Day.	<i>Flax</i> .—Damont, Reserve.

On irrigated land the Kubanka variety has produced the highest yields of spring wheat. Of the common spring wheats Marquis is perhaps the best, although Power and Champlain have given slightly higher average yields.

The hard red winter varieties, Turkey and Kharkof, are the best winter wheats for irrigated land. A selection from Turkey has produced the highest yields of the winter-wheat varieties.

Kharkof winter wheat should be sown at the rate of 5 pecks per acre on irrigated land. The best depth of seeding winter wheat is about $1\frac{1}{2}$ inches.

Winter wheat has yielded slightly more than spring wheat under irrigation.

Spring emmer has yielded less than the best varieties of barley on irrigated land. Winter emmer and spelt are not hardy and give

small yields on irrigated land. Winter rye is not as productive as winter wheat. Buckwheat has not given good yields on irrigated land at Newell.

The highest yielding varieties of oats on irrigated land are Silvermine and White Russian. The Silvermine oat produced the highest yields when sown at the rate of 8 pecks per acre.

Chevalier II and Trebi barley have yielded best under irrigation. Proso is not a very successful crop on irrigated land.

Mixtures of wheat, oats, and barley have not produced significantly higher yields of grain than the average of the crops grown alone. Mixtures of wheat and flax have yielded more than the crops grown alone, but wheat predominates in the mixture.

The Damont and Reserve varieties of flax have given the highest yields on irrigated land. These varieties also yielded best on the dry land. Flax under irrigation should be sown at the rate of 30 pounds per acre. Flax sown between May 15 and 26 produced the highest average yields on irrigated land.

Corn ground should not be plowed or subsoiled before being sown to small grains or flax.

The following varieties of grain are recommended for growing on irrigated land:

Spring wheat.—Kubanka, Marquis.

Winter wheat.—Turkey or Kharkof.

Oats.—Silvermine, White Russian.

Barley.—Chevalier, Trebi.

Flax.—Damont, Reserve.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
15 CENTS PER COPY

▽

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1040

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief



Washington, D. C.

PROFESSIONAL PAPER

April 12, 1922

CONTROL OF THE CITROPHILUS MEALYBUG.¹

By R. S. WOGLUM,² *Entomologist*, and A. D. BORDEN,³ *Assistant Entomologist*,
Fruit Insect Investigations.

CONTENTS.

	Page.		Page.
Introduction	1	Relation to Argentine ant.....	8
History and distribution.....	2	Comprehensive demonstrations of	
Economic importance.....	3	control.....	8
Host plants.....	4	Natural enemies.....	19
Description and life history.....	4	Summary.....	20
Seasonal history.....	6		

INTRODUCTION.

In the fall of 1913 a mealybug infestation was noted on citrus at Upland, Calif., over an area of approximately 3 acres. At first it was assumed to be the common mealybug (*Pseudococcus citri* Risso), a species highly damaging in some citrus localities but never before reported in the Upland district. Growers were considerably alarmed over the discovery, knowing the severity of this pest and the ineffectiveness of control in other localities. Considerable damage was done to the infested groves in a hasty attempt at eradication by fumigation. At a convention held at Ontario, Calif., on January 30, 1914, the seriousness of the problem was discussed, although no real solution was evolved. A specific determination was made at this time by Essig⁴ as Baker's mealybug (*Pseudococcus maritimus* Ehrh.), a species then considered as of minor importance to citrus. In September, 1915, Clausen,⁵ after a brief investigation of the insect,

¹ *Pseudococcus gahani* Green; order Hemiptera, suborder Homoptera, family Coccidæ.

² Resigned September 11, 1920.

³ Resigned December 5, 1921.

⁴ ESSIG, E. O. THE MEALY BUGS OF CALIFORNIA. In Calif. Mo. Bul., v. 3, no. 3, p. 110-111. 1914.

⁵ CLAUSEN, CURTIS P. MEALY BUGS OF CITRUS TREES. Univ. of Calif., Bul. 258, p. 30-35. 1915.

considered it a new species and gave it the name *P. citrophilus*. During the first four years various measures of control were tried by the growers and county and State officials without any marked success; in fact, the infested area continued to increase rapidly and the infestations became more severe.

The importance of this pest to the citrus industry and inability to control it led, in the summer of 1917, to a request for the United States Department of Agriculture to take up the problem, and the investigation was immediately started. Effective control methods were worked out in 1917 and 1918 and were generally employed throughout the infested area during 1919.

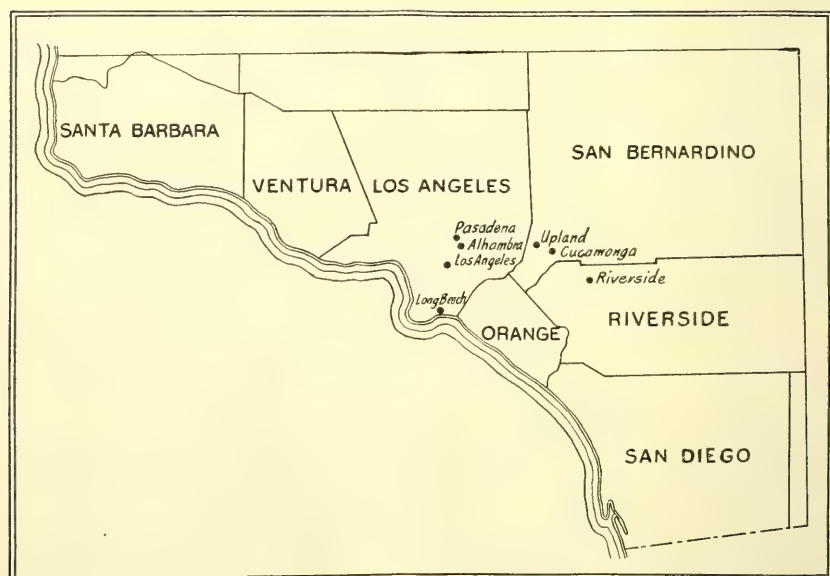


FIG. 1.—Present known distribution of the citrophilus mealybug (*Pseudococcus gahani*) in Southern California.

HISTORY AND DISTRIBUTION.

Definite records of the introduction of this mealybug into Southern California are lacking, but a study of its earliest occurrence and spread would indicate that it was brought in on some ornamental plants imported into Upland during 1910. The infestation of about 3 acres at the time of the first records (1913) had spread by the fall of 1915 to twice that area. By 1917 approximately 600 acres were infested, but since that time its spread has been greatly retarded by control means, though a few small infestations outside of the control area have been noted (fig. 1).

Shortly after the discovery of the Upland infestation the pest was found in Pasadena and has now become distributed over a consider-

able area in the northern part of the city. In 1916 over 100 acres of citrus were found to be infested at Riverside, and at the present time this infestation covers approximately 250 acres. Smaller infestations are recorded at Cucamonga and Alhambra on citrus. It is reported at Long Beach and Los Angeles on ornamentals and occurs in the northern part of the State in the San Francisco Bay region.

There is little probability of distribution by natural travel as the insect remains close to its host. The more important means of distribution are the picking boxes, picking sacks, clothing of the pickers and pruners, teams, wagons, and ladders; of slightly less importance is distribution by wind, birds, and insects. Several new infestations have been definitely traced to distribution through picking boxes previously used to transport infested fruit.

ECONOMIC IMPORTANCE.

In a severe infestation the mealybug not only masses on the twigs and foliage but also on the fruit. These masses may even cover from one-half to two-thirds of the surface and hang down in cottony festoons from the bud end. Such masses are common on severely infested lemons and on navel oranges, in the case of the latter particularly at the navel end. Where two fruits touch, a similar favored area of infestation is formed, especially on grapefruit and lemons. On young green fruit the immature forms crowd under the sepals, weakening the supporting tissues and influencing premature drop. The insects are also found in numbers on the young succulent new growth and sucker growth.

They secrete a honeydew which falls to the foliage or fruit below and in this medium grows a black fungus commonly known as "smut." The fruit and foliage become so black with this deposit as greatly to retard their development and to necessitate a special washing before the fruit can be packed.

The combination of the attack of the insects under the sepals and the deposit of "smut" frequently causes a heavy dropping of young, green fruit and also of the mature fruit, if held long on the trees. The deposit on the foliage results in a heavy leaf drop, often an almost complete defoliation of the tree. The feeding of the insects on the fruit destroys its natural gloss and often causes deep brown pittings in the rind which seriously affect the grading of the fruit. One packing-house manager reported a lowering of the grades from one severely infested orchard of from 30 to 40 per cent of the highest classed fruit. The lower grades are also seriously affected and frequently fall to culls, or unmarketable fruit. Severe infestations on lemons have been known to result in an almost complete loss of the crop, the fruit grading as culls.

HOST PLANTS.

The citrophilus mealybug is of importance commercially principally because of its infestation of citrus plants. The insect does occur, however, on a large number of other plants, principally orna-

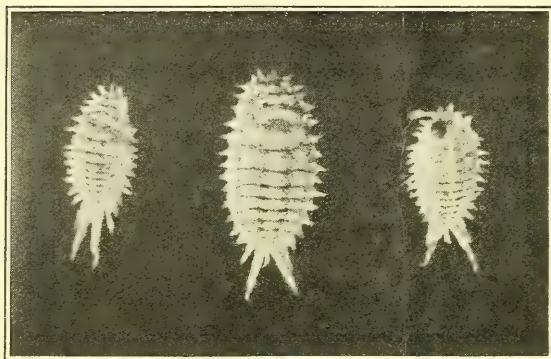


FIG. 2.—The citrophilus mealybug: Immature stages of the female.

mentals, upward of 30 different species being listed as hosts. On the citrus fruits it possibly shows its most rapid development on lemons, followed by grapefruit, navel oranges, and Valencia oranges, in the order given. It has been observed to develop very rapidly on the rhubarb, potato,

grevillea, walnut, grape, and on species of *Coleus* and *Pittosporum*.

DESCRIPTION AND LIFE HISTORY.

The synonymy of the citrophilus mealybug was first correctly determined by G. F.

Ferris in August of 1919.⁶ As stated, this insect was first confused with the common mealybug and later, by Essig, with Baker's mealybug. Clausen, in September, 1915, noted certain differences in him to describe it as characters which led a new species (*P. citrophilus*) but Ferris found that the same insect had been de-

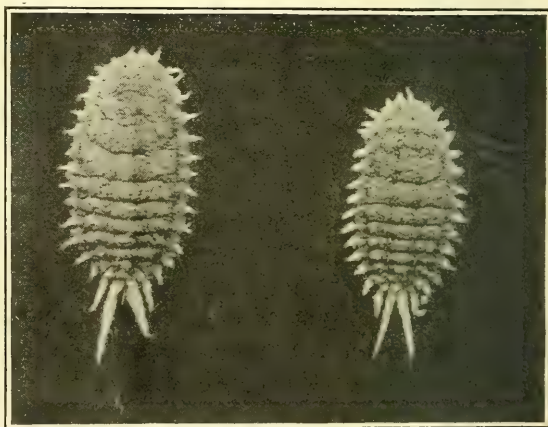


FIG. 3.—The citrophilus mealybug: Mature stages of the female.

scribed by Mr. E. E. Green during May, 1915, as *P. gahani* from specimens taken from *Ribes sanguinea* in London, England. Un-

⁶ FERRIS, G. F. OBSERVATIONS ON SOME MEALY-BUGS (HEMIPTERA; COCCIDAE). In Jour. Econ. Ent., v. 12, no. 4, p. 292-293. 1919.

fortunately the scientific name *citrophilus* had been adopted as the common name long before the correct determination was given.

The eggs are deposited in a flocculent mass behind the adult female and may number up to 1,000, though from 500 to 600 is the average. The period of incubation during the warm season is from 7 to 10 days.

Except in size, the larvæ are similar to the adult in appearance after the first molt and pass through three molts before reaching maturity. The characteristic arrangement of the wax is not strikingly noticeable until after the third molt. The immature stages of the female are illustrated in figure 2, the mature stages in figure 3.

The following description of the adult of *Pseudococcus gahani* is by Mr. E. E. Green:⁷

Adult female thickly coated with greyish-white mealy secretion, which is thinner in the folds of the segments and in the depressed areas. These depressions are in four more or less confluent longitudinal series which are more marked on the posterior half of the body. The darker color of the insect showing through the mealy covering at these spots, produces a distinct symmetrical pattern. There is a complete marginal series of 33 short conical waxy processes, an anterior and posterior pair being usually larger than the others. On each side of the anal orifice is a much longer, broadly laminate process which is transversely curved and spirally twisted, and between these is a pair of shorter processes, which together form a tube. Antenna, 8-jointed, the 8th longest; first joint strongly developed, approximately as long as it is broad; antennal formula (excluding 1st), 8 (3,2), (5,4,6,7), the last four being only approximately equal and varying slightly in their relative positions in the series. Limbs well developed; tarsus approximately half the length of the tibiae. Eyes prominent. Mentum distinctly biarticulate; longer than broad; terminal joint longest, acutely pointed. Dorsal glandular pits present but rather inconspicuous. Anal ring large and conspicuous, with six long stout setae. Anal lobes broadly rounded; only slightly prominent; more strongly chitinated than the surrounding parts, the margins of the chitinous area sharply defined; each with two stout conical spines, several fine hairs, some conspicuous circular pores, and a terminal seta which is approximately equal in length to those of the anal ring. Margins of segments, each with a small protuberance, bearing similar spines, pores and hairs, all of which become smaller and less conspicuous as they approach the anterior extremity. Derm with scattered, small, and inconspicuous pores. Many longish hairs on under-surface of head. Length, 2.50 to 3 mm. Breadth, 1.25 to 1.50 mm.

Adult male similar in appearance to that of *Ps. citri*. Length, 1.50 mm.

Though the structural characters agree somewhat closely with those of *citri*, the general appearance of the living insect is strikingly different, and it is of a much more active habit. * * *

Mr. Gahan observes that the insect, when irritated, exudes "a claret coloured liquid in round drops, two close to the head end and two at the tail end." The exudation evidently emanates from the glandular pits that are present in the positions indicated. He further remarks that the "dark-coloured secretion soon dries, looking like a small balloon. The liquid hardens into a solid substance which resembles lac or something of a similar nature."

⁷ GREEN, E. E. OBSERVATIONS ON BRITISH COCCIDAE IN 1914, WITH DESCRIPTIONS OF NEW SPECIES. In Ent. Mo. Mag., v. 51, p. 179-180. 1915.

SEASONAL HISTORY.

A most important feature in the biology of this insect was determined by observing the habits of the insect during the spring migration. The females, which during the winter have developed almost to maturity on the twigs, foliage, and fruit, migrate, in the spring, down the limbs to the trunk to oviposit. This migration usually begins during the early part of April and continues throughout the month of May. It is estimated that over 90 per cent of the insects take part in this movement, although not all have reached full development at this time. They settle on the rough places in the bark of the main limbs and trunk and soon begin ovipositing. On severely infested trees these accumulations of females with their cottony egg masses appear as large bunches of cotton hanging from the limbs and massed about the trunk and may be collected by handfuls. (Fig. 4.) These egg masses begin to hatch the latter part of May or early part of June, and the young larvæ start a migration back up the main limbs to the foliage and green fruit. The young settle along the midribs of young foliage, on the tenderest twigs, and under the sepals of the green fruit. Here they start feeding and their development is comparatively slow. By late fall many have become half grown and have settled in the more secure positions on the bud end or navel end of the fruit or between the fruit in clusters, and their development from then on is very irregular. During the winter many may have reached the oviposition stage, but the majority of the insects are still immature. There is a great reduction of numbers throughout the late fall and winter; in fact, on many trees it is often difficult to find them, but with the opening of spring the matured forms again enter into the migration. There is only one main generation a year, although the retarded development of some insects and the hastened development of others cause an overlapping of generations and consequently the presence of some insects in various stages of development at different times of the year. There is a possibility of an offhatch or overlapping of generations in the appearance of egg masses during the winter. This occurrence, however, is of minor importance in that the numbers of the mealybug are at their lowest at this time and most of the damage to the host has already occurred.

The young larvæ hatching from the egg masses in June are often killed by hot weather. In the summer of 1917 a very large percentage of the larvæ and eggs were destroyed by a short period of hot weather when the temperature exceeded 110° F. Again in the summer of 1918 the hatching occurred just before a warm spell and many larvæ were killed. That weather conditions and natural enemies are powerful factors in the control of this mealybug is very evident,

for only a small percentage of the larvæ hatching from the egg masses ever reach maturity. Many are washed off and destroyed by

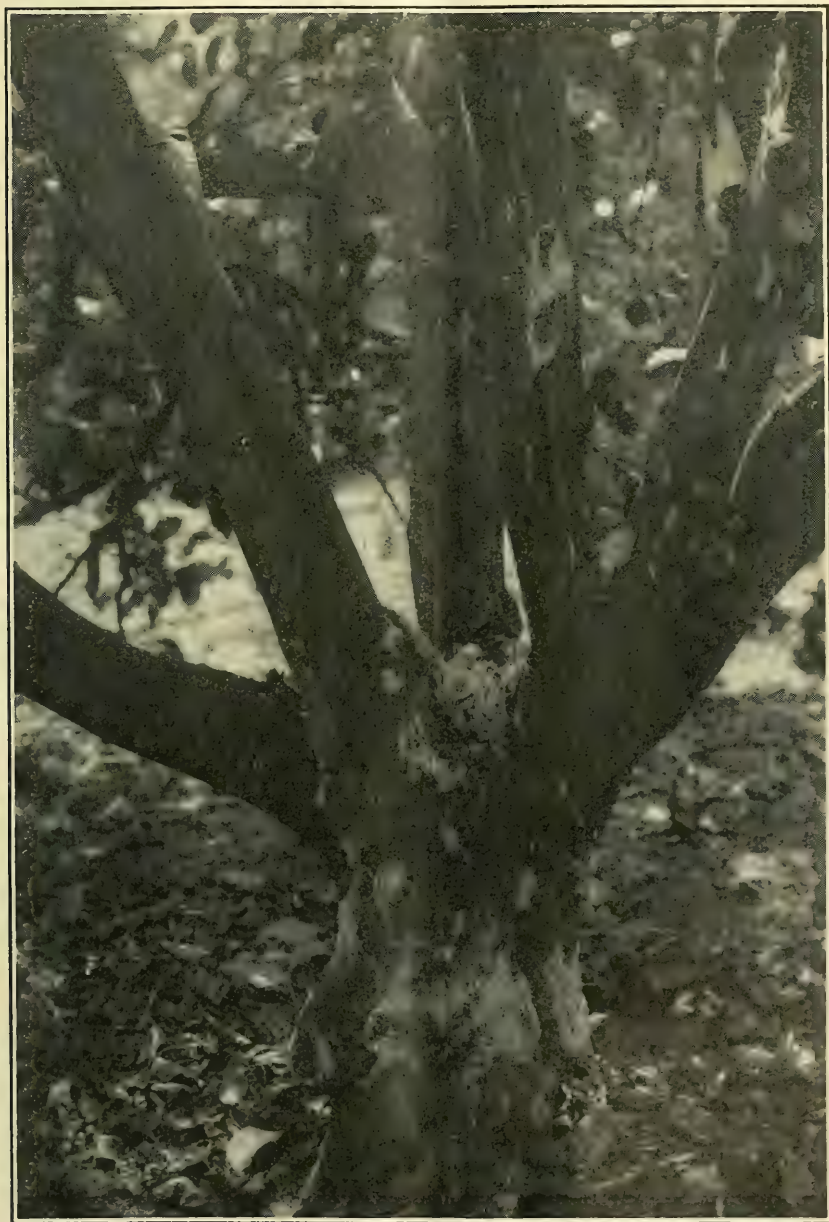


FIG. 4.—Trunk of lemon tree showing masses of ovipositing females of the citrophilus mealybug following the spring migration.

rain during the winter months and the development of others is greatly retarded during this cooler period.

RELATION TO ARGENTINE ANT.

In not a single instance has this mealybug become serious excepting where it has been attended by the Argentine ant (*Iridomyrmex humilis* Mayr). One case was noted in 1918 at Cucamonga where the mealybug had been observed for several years previous to that time, but never considered as doing any commercial damage. During the year 1918-19 the area became infested with Argentine ants and in the summer of 1919 control work on the mealybugs and ants became imperative. In every known locality where this mealybug now occurs it is attended by this particular ant.

COMPREHENSIVE DEMONSTRATIONS OF CONTROL.

EXPERIMENT NO. 1. DEMONSTRATION PLOT.

The orchard selected for demonstration of control methods at Upland in the summer of 1917 was near the center of the mealybug infestation (fig. 5) and was considered one of the worst infested groves, both as regards mealybugs and ants, in the colony. It consisted of two distinct plots of 10 acres each. The first 10 acres were planted to Valencia (6 acres) and navel (4 acres) oranges and had in all 674 trees. The second plot was planted largely to navel oranges (8 acres), with approximately 2 acres of old lemons, making a total of 676 trees. The trees were large and the lower limbs rested on the ground. A careful inspection of the Valencia fruit in August, 1917, showed an average of over 50 per cent of the fruit on each tree infested, with from 20 to 35 mealybugs to a fruit, besides the infestations on the foliage and sucker growth. Many of the trees carried from 90 to 100 per cent of infested fruit, with the foliage and new growth as severely infested. Practically every tree had a trail of ants and many were attended by two and even three trails. The infestation on navel oranges and lemons in the second 10-acre plot was as severe but showed only on the small green fruit and new growth.

ARGENTINE ANT ERADICATION.

Investigations, by the senior writer, of the common mealybug of citrus trees resulted in the discovery that this insect was effectively controlled by natural enemies, principally predators, in Argentine ant-infested territory provided the ants were eliminated. Therefore, when a survey showed that the citrophilus mealybug occurred exclusively in districts frequented by these ants, the first efforts were confined to a campaign against the ant in the hope that only such activity would be necessary, as had proved the case for the common mealybug.

The first operation undertaken was the trimming up of the branches from the ground so as to force the ants to ascend the trunks where the poison was placed. Two men trimming averaged 78 trees per day of 8 hours at a cost of approximately 8 cents per tree. The orchard was in a state of clean cultivation and entirely free of weeds beneath the trees.

Ant control was begun on about 1 acre of the first 10 in September, and the remainder completed by October 5, 1917. The second 10 was covered by ant control in November, 1917. An arsenical-sweetened sirup, known as the Barber formula, was used for the first distribution in this orchard, a small amount being placed in each container, one of which was attached to each tree. (Fig. 6.) Complete eradication was effected the following spring at a cost of 2.6 cents per tree on the first 10 acres and at a cost of 4.9 cents per tree on the second 10 acres. The control is summarized in Table 1.

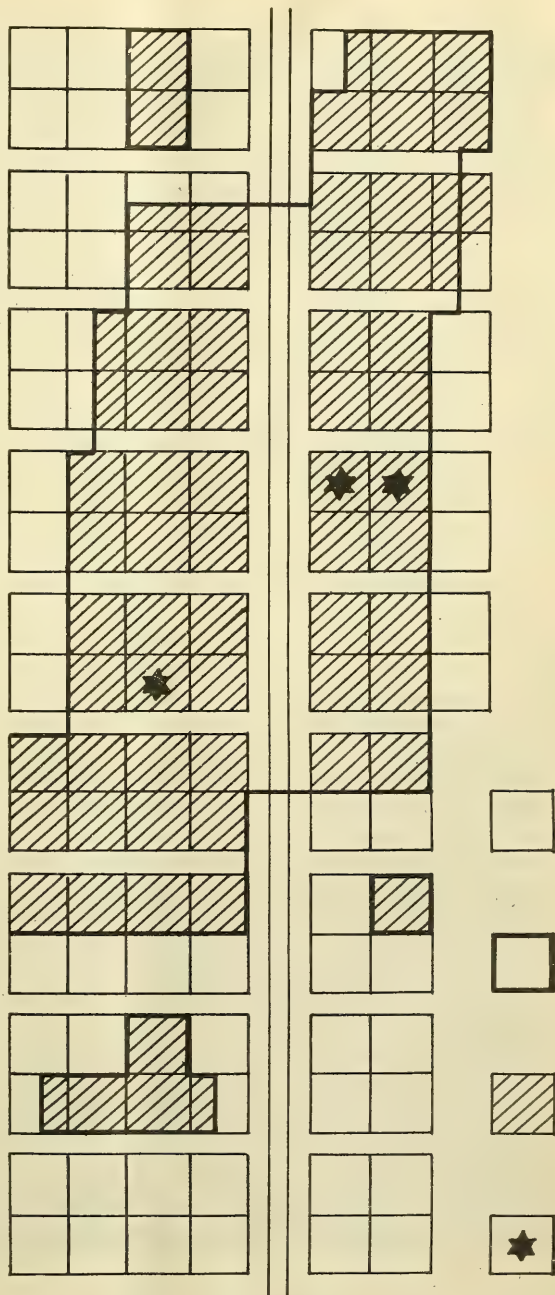


FIG. 5.—*Citrophilus mealybug* control areas, Upland district, 1917-1919.



FIG. 6.—Tree trunk showing burlap band and ant poisoned-sirup can in position.

TABLE 1.—*Control of the Argentine ant in a citrus orchard at Upland, Calif., 1917.*

DEMONSTRATION PLOT, FIRST 10 ACRES, 674 TREES.

Date of inspection.	Poison distributed.	Trees with ants.					Check area.				
		Clean.	Very light trail.	Light trail.	Medium trail.	Heavy trail.	Clean.	Very light.	Light.	Medium.	Heavy.
Sept. 23.		5	99	312	133	125					
	Oct. 5		Over entire area.								
Mar. 24.		671		3							
	Apr. 9		Only on trees with ants.								
Apr. 9.		648	20	6							
	June 17		Only on trees with ants.								
June 17.		642	17	15							
June 29.		672	2								

DEMONSTRATION PLOT, SECOND 10 ACRES, 676 TREES.

Sept. 23.		2	157	266	107	68		9	23	20	24
	Nov. 5		On 600 trees.					Trap nest under 76 trees.			
Mar. 20.		391	119	61	15	14	8		19	23	26
	Apr. 1		On 600 trees.								
	Apr. 5		On 76 trees.								
Apr. 30.		546	39	10	4	1	57	13	5	1	0
June 11.		577	18	5	0	0	75	1	0	0	0
June 29.		593	7	0	0	0	76	0	0	0	0

BURLAP BANDING.

Although by winter the ants were controlled and early the following spring were almost completely eradicated, the mealybugs continued in severe infestations and during the latter part of March were noted to begin descending the tree trunks. The descent continued to increase in April and no large number of natural enemies appeared as was anticipated. It soon appeared that elimination of the ant was not alone sufficient to bring about control of the citrophilus mealybug, as had proved the case for the common mealybug. The citrophilus mealybug species was not attacked by either numerous or effective natural enemies. The necessity of artificial means of control to supplement ant eradication was thus at once apparent.

A study of the habits of this mealybug showed a spring migration to the trunk and rough places on the main branches where egg masses for the succeeding generation are deposited. The accumulation of insects and egg masses in cases of severe infestations, as previously pointed out, became so great as frequently to present the appearance of large tufts of cotton. This massing on the trunk and lower branches presented a favorable point of attack and the spraying of these masses with an effective insecticide promised a great reduction of the total insects present. It was noted, in the case of some trees which had been banded with cotton bands by an orchardist at Upland in 1915, that these acted to attract the ovipositing females beneath them in great masses. Since cotton bands were scattered by the winds and birds, it was decided to substitute burlap and ac-



FIG. 7.—Trunk of lemon tree with burlap band removed showing masses of ovipositing females of the citrophilus mealybug collected under band.

cordingly in the spring of 1918 the trees in the demonstration orchard were thus banded. (Fig. 6.) A band of burlap about 6 inches wide was wound around the trunk just below the main branches and caught at each end with a finishing nail. The migrating females

readily collected under the bands preparatory to oviposition. (Fig. 7.)

The success of burlap bands as used on the demonstration plot led the growers throughout the infested area to adopt the practice. This necessitated a large supply of burlap bands and the problem was solved by buying the burlap of 30-inch width in bolts of about 100 yards. The bolts were cut at a printing office under a large paper knife into six rolls, 5 inches in width, which could readily be carried into the orchard and cut in appropriate lengths for individual trees. The ends of each band were fastened over a 4d finishing nail driven into the trunk of the tree. The average orchard of 900 trees was banded with one full bolt of burlap. The average cost in 1919 was as follows:

1 roll burlap (100 yards)-----	\$12. 60
Cutting-----	1. 00
Nails-----	.15
Labor (1 man, 1 day)-----	3. 00
	16. 75

Cost per tree, approximately \$0.02.

During April and May insects continued to descend in great numbers, the burlap bands proving a center of attraction. In cases of light infestation the majority of the descending insects would settle beneath the band, and this was particularly true on smooth-barked orange trees. (Fig. 8.) Lemon trees with the more irregular trunks and depressions where the main branches join the trunks offered favored places for the mealybugs to settle, although even these seemed less favored by them than the bands. By the latter part of May hatching started, following which the larvæ migrated back to the foliage and fruit on the tree. Before this happened the bands were removed and dipped in an effective insecticide, usually pure petroleum distillate, and the trunks were then sprayed.

SPRAYING.

Spraying operations on the first 10 acres were conducted on May 23 and 24, and on June 6 and 7 on the second 10 acres. Only the main limbs and trunks were sprayed and for this a petroleum distillate-soap emulsion applied with a power sprayer at 150 pounds pressure proved most satisfactory. Two leads of hose with angled Bordeaux nozzles were used. The burlap bands were removed and thoroughly sprayed as the trunks were being sprayed. The formula used was as follows:

Distillate 28° to 30° B-----	gallons--	10
Soap powder-----	pounds--	20
Water to make-----	gallons--	200

If a lighter oil, as stove distillate, is used, the amount should be increased to 15 gallons. A good agitator is necessary in mixing the spray. After a few

inches of water are in the bottom of the tank, the soap powder is sifted in as the tank is being filled and the agitator is running. The oil is added last before the tank is full.



FIG. 8.—Three burlap bands from the trunks of orange trees following spring migration of the *citrophilus* mealybug.

It was felt that the spraying of the bands was not entirely satisfactory unless the greatest care was used, so in subsequent work it was decided to dip them just before spraying. The application, to

be effective, must be thorough and to accomplish this it is necessary to go beneath the tree. The most satisfactory work was done when the nozzle was connected directly to the hose, allowing free manipulation in any direction. A long rod should never be used as it does not allow the ready manipulation necessary on heavily branched trees to spray from any direction.

The trees on the demonstration plot were of an open type with smooth trunks and high headed, so they could be entered with ease and quickly and thoroughly covered with spray. It required only $3\frac{1}{2}$ tanks of spray to cover each of the 10 acres. The cost (1918) is summarized herewith:

35 gallons distillate, at \$0.05 per gallon-----	\$1. 75
70 pounds soap powder, at \$0.05 per pound-----	3. 50
Team and teamster for $1\frac{1}{2}$ days-----	9. 00
Two men spraying for $1\frac{1}{2}$ days-----	9. 00
Gasoline and oil-----	1. 25
Total-----	24. 50

Cost per tree, \$0.036.

The time, $1\frac{1}{2}$ days, included considerable engine trouble. Fifty-two trees were sprayed in 30 minutes. A tank of spray (200 gallons) covered approximately 200 trees.

Several days after the spraying the burlap bands, now dry, were replaced on the tree trunks and left for a year. At no time were insects noted under the bands except an occasional one, which the natural enemies destroyed before oviposition was completed.

Throughout the following fall and winter (1918-19) it was very difficult to find even individual mealybugs, and the packing house handling the fruit reported it to be cleaner than any that had been turned in during the five preceding years, with an increase of grade amounting to from 30 to 40 per cent.

During the spring of 1919 an inspection was made of the demonstration plot and very few mealybugs and no ants were found. Under the old bands not more than 10 to 12 insects were found on any one tree. The grove was sprayed again by the owner in June of 1919, as outlined above. An inspection in May, 1920, showed a practically clean grove, not more than 5 insects being found under the bands of any tree, and most of the trees were entirely free of mealybugs.

EXPERIMENT NO. 2. FARLOW GROVE, 888 TREES.

In the summer of 1919 a second demonstration plot was employed which consisted of 10 acres of heavily infested oranges. Ant control and banding had been carried on the previous spring, and the ants were greatly reduced at the time of spraying. In this grove, as in the former, a power sprayer with two leads of hose and Bordeaux

nozzles were used. Distillate-soap powder emulsion, soap powder, and water were used, as shown in Table 2, and data were gathered on the efficiency of the different solutions.

Before the spraying started a man was sent through to remove the heavily infested bands, dip them in pure distillate, wring them out, and place them to one side to dry.

TABLE 2.—*Summary of spray operations against the citrophilus mealybug.*

Spray.	Total number of trees sprayed.	Average number of trees per tank.	Average spray time per tank.	Average number of gallons per tree.	Effective-ness of spray.
5 per cent distillate-soap powder emulsion.....	777	59	<i>Min.</i> 58	3.4	Excellent.
Water.....	69	34	85	5.7	Poor.
40 pounds soap to 200 gallons water.....	42	42	45	4.8	Do.

Both the water and soap-powder treatments were discontinued, as it was found to be impractical in application to get a thorough clean-up of the egg masses. The distillate-soap emulsion was quicker in application and more effective.

The bands were replaced shortly after the completion of the spray work, and field observations made from time to time throughout the following year. Though some mealybugs appeared under the bands following the spraying, they were completely controlled by natural enemies and required no further treatment. Throughout the fall and winter no mealybugs were apparent, and in the spring of 1920 so few mealybugs appeared under the bands that hand treatment was all that was required. The grove is now commercially clean, and there has been a marked increase in the grade of the fruit.

The data obtained in this experiment not only demonstrated the practicability and efficiency of the distillate-soap emulsion but also demonstrated the advisability of proper pruning before spraying. The trees on this grove were low on the ground and it was difficult to treat the trunks owing to low branching and inside growth. In consequence of this condition it took much more material and a longer time to make the application. The cost of spraying was as follows:

Removing and dipping bands, 1 man, 1 day.....	\$3.00
16½ tanks spray:	
330 pounds soap powder, at \$0.07 per pound.....	23.10
165 gallons distillate, at \$0.07 per gallon.....	11.55
Two men, at \$4 per day, 2 days.....	16.00
Team, at \$4 per day, 2 days.....	8.00
Gasoline and oil, 2 days.....	2.50
Total.....	64.15

Cost of \$0.072 per tree.

HAND-TREATMENT METHOD.

In a 5-acre citrus orchard, comparatively lightly infested with mealybugs and banded early in the spring of 1919, the hand-treatment method was effectively employed. This consisted of removing the bands and dipping them in a bucket of 25 per cent distillate-soap emulsion, wringing the bands out dry, scrubbing the trunks with a suitable brush, and replacing the bands.

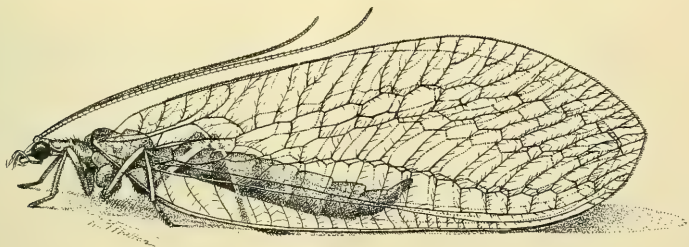
Different strengths of the emulsion were tried with results as shown in Table 3.

TABLE 3.—Results of hand-treatment method against the *citrophilus mealybug*.

Strength of solution.	Effectiveness—	
	On adults.	On egg masses.
5 per cent.....	Poor killing.....	No effect.
10 per cent.....	50 per cent killing.....	Poor.
25 per cent.....	100 per cent killing.....	Excellent.

The 25 per cent solution is prepared as follows:

Place 6 quarts of water in a bucket and thoroughly dissolve $\frac{1}{2}$ pound of soap powder. To this slowly add 2 quarts (30° Baumé) distillate while constantly stirring. Attach the bucket pump and pump the solution back into the bucket through a mist nozzle until a perfect emulsion, free of oil globules, is obtained. The emulsion should be used soon after preparation.

FIG. 9.—Adult of *Chrysopa californica*. Much enlarged.

Several growers have used this method successfully on light infestations, where followed up at intervals of about every two weeks from the middle of May to the latter part of June, at a cost of 2 cents per tree for each treatment. It is as important to effect ant eradication when this method is employed as it is with the regular trunk-spray method.

CONTROL WORK—UPLAND DISTRICT, 1919.

The great success of the demonstration work of 1917 and 1918 led to the general adoption of the control methods by the growers throughout the infested area. (Fig. 5.) Up to and including 1919 ant control was practiced on 630 acres. The entire mealybug-infested

acreage was banded with burlap in the spring of 1919. Of the area infested with the mealybug in that section all but 10 acres were sprayed according to the methods outlined, with excellent results throughout. The 10-acre orchard was left as a check for control by natural enemies.

The ant control was handled partly by the growers themselves, partly by the citrus associations of which the orchardists were mem-

bers, and partly by contract operators. The sirup was for the most part prepared by the citrus associations, or purchased from druggists at a cost of \$1.50 to \$2 a gallon. The spice tin was the preferred container. The average cost to the grower for ant control, including refilling where necessary, was 4 to 6 cents per tree. The cost of burlap banding averaged 2 cents

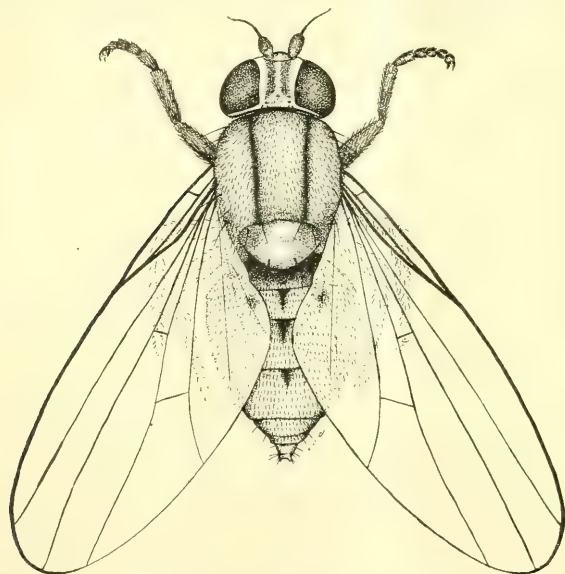


FIG. 10.—Adult of *Leucopis bella*. Greatly enlarged.

per tree. The cost of trunk spraying varied. On dense, unpruned lemon trees, headed low, spraying proved somewhat difficult and slow. The amount of material used on such trees was also greatest. High-headed orange trees with smooth trunks were most easily and effectively sprayed.

These spray operations were conducted by the growers and commercial outfits and an average of 10 acres a day was covered at a cost approximating the figures given for the two demonstration plots, the cost being more or less proportional to whether the trees were well pruned and open or unpruned and difficult to spray. Work carried out by the owners themselves was for the most part thoroughly done. A few orchards were trunk-treated by hand.

The general results of the control campaign of 1919 at Upland were very gratifying. Orchards which had shown severe infestations in the spring of 1919 were commercially clean in the spring of 1920. The reduction in grade or total loss of fruit from mealybugs had been reduced to a negligible factor. Packing-house managers and growers were convinced that the citrophilus mealybug was no longer a menace to their orchards and that the control of

this insect was on such an effective commercial basis that timely future attention would effectively hold it in check.

NATURAL ENEMIES.

Though the ant control, banding, and trunk spraying have given excellent control of the citrophilus mealybug, the importance of its natural enemies in conjunction with this artificial means of control needs emphasis. The natural enemies are very effective against light infestations, if the ants are not present, and even in heavier infestations are important in assisting to destroy the insects on the foliage and trunks following spray treatment. The most effective natural enemies present in the groves are all predators and appear to rank in order of importance as follows: *Chrysopa* spp. (fig. 9), *Leucopis bella* Loew (fig. 10), and *Scymnus sordidus* Horn (fig. 11). They breed freely in the cottony mass of ovipositing females on the trunks, although by no means noticeably reducing the

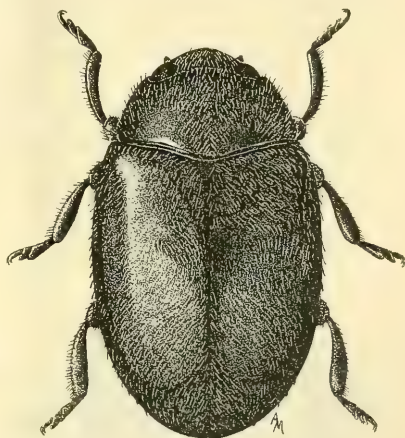


FIG. 11.—Adult of *Scymnus sordidus*. Greatly enlarged.



FIG. 12.—Larva of *Cryptolaemus montrouzieri*. Much enlarged.

mealybug on heavily infested trees. It is, however, following the migration of the mealybug larvæ to the tender fruit and foliage that the effectiveness of these natural predators is most felt. Here they search out and destroy the young mealybugs, and in the case of light infestations frequently prevent the development increasing to severe proportions. *Chrysopa* and *Leucopis* are usually most numerous during the late spring and summer, while *Scymnus* is most effective during the early fall.

The natural predators of primary importance in controlling the common mealybug, namely, *Sympherobius* spp. and *Hyperaspis lateralis* Muls., are of very secondary value against the citrophilus

mealybug. *Cryptolaemus montrouzieri* Muls. (figs. 12, 13), however, is very effective against either species. This predator was first tried against the citrophilus species by the writers at Alhambra during

1916 and proved so effective that several hundred were distributed beneath a tented citrus tree at Upland during the autumn of 1917. Some specimens successfully passed the winter and started breeding freely the following spring. The Insectary Branch of the California State Commission of Horticulture followed the writers' lead and has since distributed many thousands over the Upland district, with such successful returns that the work should be supported and continued.

SUMMARY.

(1) Ant control. This is most effectively accomplished by the use of a special arsenical poisoned sirup in small containers, one to each tree. Best results follow distribution during the autumn or spring.

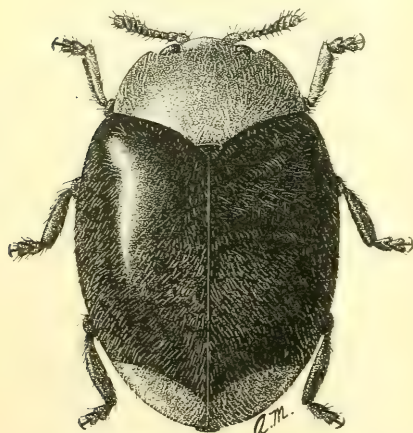


FIG. 13.—Adult of *Cryptolaemus montrouzieri*. Much enlarged.

(2) Trunk banding. Strips of burlap about 5 inches wide should be placed around each tree trunk, from February to April, to attract ovipositing female mealybugs.

(3) Removal and dipping of burlap bands in distillate. This should precede the trunk spraying. The bands should be dry when replaced after the trunk treatment.

(4) Trunk treatment. Spray thoroughly with distillate-soap powder emulsion after the mealybugs have massed on the trunks and just before the eggs begin to hatch. This is usually during the latter part of May.

(5) The propagation and distribution of *Cryptolaemus montrouzieri*, *Leucopis bella*, *Chrysopa* spp., and *Scymnus sordidus* are to be recommended.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY

▽

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1041



Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.

January 11, 1922

A STUDY OF SWEET-POTATO VARIETIES, WITH SPECIAL REFERENCE TO THEIR CANNING QUALITY.

By C. A. MAGOON and C. W. CULPEPPER, *Office of Horticultural and Pomological
Investigations.*

CONTENTS.

	Page.		Page.
Introduction-----	1	Consistency-----	16
Chemical composition of sweet po- tatoes-----	3	Varieties and strains of sweet pota- toes used in these tests-----	23
Experimental canning tests-----	6	Summary-----	30
Discoloration-----	13	Literature cited-----	33
Heat penetration and sterilization--	16		

INTRODUCTION.

To the people of the Southern States the sweet potato constitutes one of the most important food crops. Owing, however, to its highly perishable nature in the raw state, the shipment of this crop to distant markets is attended with considerable risk. The introduction of modern methods of preservation is overcoming some of these difficulties, and the sweet potato is rapidly coming into its own as an important addition to the dietary of the American people, North as well as South. In 1917 the total pack of canned sweet potatoes, according to figures compiled by the United States Food Administration, amounted to 238,250 cases of cans of all sizes; in 1920 the pack, according to the best figures obtainable, was 473,384 cases (all sizes being reduced to No. 3 cans).

For a number of reasons it is important that the canning of sweet potatoes and the wider use of the product by the housewife should be encouraged. The sweet potato, as shown by analysis and by the experience of its users, is very high in food value; it is adapted to a wide variety of culinary uses; and a greater market for the canned product only awaits development.

The sweet potato (*Ipomoea batatas*) belongs to the same family botanically as the common morning-glory (Convolvulaceæ). Although it frequently blossoms and even produces seed in the extreme southern portions of our country, propagation as practiced is not by the use of seed but of slips and vine cuttings which are set in the field.

In vine and leaf characters considerable differences are observed among the varieties, some forming long trailing vines, while in others the trailing habit is greatly restricted or almost entirely absent. The shape and size of the leaves also differ widely, varying from the small entire heart-shaped leaves, which closely resemble those of the morning-glory, to large, shouldered, and even deeply cleft forms, which bear little resemblance to those of their close relative. Considerable variations both in size and shape often may be observed upon the same plant.

The edible portions of the plant are produced underground as modified and greatly enlarged roots. True tubers, as found in the case of the Irish potato, are never formed. Among varieties these enlarged roots vary greatly in size, shape, color of the skin and of the flesh, in sugar content, and in cooking and table qualities. In contrast to the sweet potatoes usually seen in markets and retail stores the edible roots in certain varieties may attain a length of 18 to 24 inches; in shape they vary all the way from long, cylindrical, root-like forms to spindle-shaped and more or less globoid individuals; and while in certain of the varieties the shape is more or less uniform, in others wide differences are observed in the same plant. The size is variable also, and in some instances individual roots may attain a diameter of 4 to 6 inches, weighing from 5 to 6 pounds. The surface may be smooth and regular, veined, or even deeply grooved.

The color of the skin passes through all gradations from almost white to cream, warm buff, cinnamon buff, and light Corinthian red to dark vinaceous; and the flesh among the different varieties may vary from almost white to carrot red in color.

When freshly cooked, still further differences are observed. The color of the flesh, which in the raw potato is more or less unevenly distributed, appears more uniformly dispersed in the cooked potato, which may assume cream, buff, empire yellow, orange, or other intermediate colors, depending upon the varieties concerned. In some there is a marked tendency to darken on exposure to the air, while in others this is shown to a much less extent.

The consistency, texture, flavor, and sweetness also show wide variations. These differences among the varieties, together with their difference in behavior in storage, make the selection of suitable varieties for table use, for the manufacture of numerous sweet-potato products, for commercial storage and shipment, and for the produc-

tion of attractive and desirable canned goods of very great importance.

The investigations reported upon in this paper were made possible by the presence at the Arlington Experimental Farm, where this work was done, of variety test plats, where upward of 40 varieties and strains of sweet potatoes have been under study for a number of years. J. H. Beattie and C. J. Hunn, of the Office of Horticultural and Pomological Investigations, Bureau of Plant Industry, have these varieties under observation, furnished much of the raw material, and otherwise facilitated the work. No claim is made that all varieties are embraced in this study, but all those generally considered as important are included. There has been much confusion in the variety names of sweet potatoes, and it is hoped that the studies now in progress in the Office of Horticultural and Pomological Investigations will make clear the relationship of the numerous strains.

It is possible that under different climatic and soil conditions the same varieties might have given slightly different results from those here reported. Comparative canning tests upon potatoes from other sections of the country have not been made, though these would have been of interest. The potatoes used were handled under carefully controlled conditions, and the uniform treatment which they received makes possible a direct comparison of the merits of the different varieties. This has been the object of the work, and it is believed that the information presented will be found of service not only to those interested in the canning of this product but also to those following other methods of sweet-potato utilization.

CHEMICAL COMPOSITION OF SWEET POTATOES.

In entering upon a study of this sort it is necessary to know something of the chemical composition of the material under consideration. Table 1, taken from the work of Atwater and Bryant (1),¹ shows the chemical composition of both the fresh sweet potato and the canned product.

TABLE 1.—*Chemical composition and calorific value of fresh and of canned sweet potatoes.*

Condition.	Constituents (per cent).						
	Water.	Protein.	Fat.	Total carbo- hydrate (including fiber).	Fiber.	Ash.	Fuel value per pound (calories).
Fresh, raw.....	69.0	1.8	0.7	27.4	1.3	1.1	570
Canned.....	55.2	1.9	.4	41.4	.8	1.1	820

¹ Serial numbers in parentheses (*italic*) refer to "Literature cited" at the end of this bulletin.

It will be seen from Table 1 that the sweet potato has a low moisture content: it is high in total carbohydrates and low in fat, fiber, and protein. The protein content is slightly lower than that of the Irish potato; but about half of the total nitrogen calculated as protein in the Irish potato is really in the form of amids, whereas in the sweet potato, as shown by Keitt (11), no amids are present. The low crude-fiber content indicates high digestibility, and the fuel value is also seen to be high.

From the standpoint of the canner the acidity of the sweet potato is of considerable importance, since it affects the transformations which take place within the can both during and after processing and likewise has an important bearing upon sterilization. Published data upon this subject, however, are meager. Bigelow and Cathcart (2) approached the subject from the standpoint of the hydrogen-ion concentration and give the results of six determinations upon canned sweet potatoes from different sources packed in No. 2½ and No. 3 cans and processed at different temperatures for variable lengths of time. Their determinations place the P_h value for sweet potatoes at between 5.27 and 5.56, with an average of 5.39. According to the findings of these authors the hydrogen-ion concentration of the canned sweet potatoes is a little lower than string beans and green peppers and slightly higher than spinach. Lima beans, peas, and corn show a considerably less hydrogen-ion concentration, and pumpkins and carrots somewhat more.

In the present investigations the titratable acidity was determined upon the canned material of each of the varieties and strains under study. The material examined was in the form of pie stock, which was packed dry into No. 2 tin cans and processed for 45 minutes at 116° C. Samples of 10 grams each were shaken up in 100 c. c. of distilled water, boiled one minute to expel carbon dioxid, and titrated with N/10 NaOH, using phenolphthalein as an indicator. From 3.2 to 7.3 c. c. of the standard alkali were required to neutralize the acidity of these 10-gram samples. These figures represent the extremes, the average of the 43 varieties and strains being 4.5 c. c., which shows that the sweet potato is quite low in acidity. The average titratable acidity was slightly higher in samples packed in 1920 than those packed in 1919, but this fact is not considered significant, as in some varieties the acidity was higher in 1919 than in 1920. The differences in acidity among the varieties were small, and in these tests they could not be correlated with keeping qualities, discoloration, or any other significant quality. They therefore seem to be too small to be of importance.

The most important constituents of sweet potatoes are the carbohydrates, and since the nature and relative proportions of these fundamentally affect the physical character and quality of the

canned product it is extremely desirable to know something about them. Shiver (18), McDonnell (15), and Keitt (11, 12, 13) have shown that the sweet potato has a high starch content, with somewhat variable quantities of cane sugar and dextrose. The analyses of these writers show the content of starch to vary between about 10 and 29 per cent in the freshly dug potatoes, the average being approximately 20 per cent. Considerable differences in this respect are noted in the varieties at the time of digging. Keitt (12, 13) has given special attention to the moisture content and to the proportions of the various carbohydrates in sweet potatoes when dug at different stages of maturity. He notes that in the small potatoes the moisture content is comparatively low, while the starch and sugar are high; then comes a period of rapid growth, during which the water increases and the starch and sugars decrease; and as the potatoes approach maturity the tendency is for the starch to increase and the total sugars and water to decrease. The relative proportions of cane sugar and dextrose are shown to vary greatly, dependent apparently upon meteorological conditions. The total sugars during the periods of the tests varied between about 2 and 6 per cent.

During the curing process and in storage physiological changes take place which transform part of the starch to sugars and intermediate products. These transformations have been followed carefully by several investigators. Harrington (7) was the first investigator, apparently, to note these changes. In a study of 16 varieties, covering a period of a little more than four months, this worker found that the average water content decreased from 71.35 to 63.5 per cent, the invert sugar increased from 3.17 to 4.63 per cent, and the total sugars increased from 6.27 to 12.31 per cent. Taking as the cane-sugar content the difference between the total sugars and the invert sugar, it is found that the cane sugar increased from 3.1 to 7.68 per cent during this period. Shiver (18) obtained similar results, but noted a slight increase in the moisture content during storage. He showed, however, that there may be either an increase or a decrease in the moisture content, depending upon the storage conditions. Hasselbring and Hawkins (8, 10) have studied the chemical changes taking place when sweet potatoes are stored at different temperatures. They find a very great decrease in the starch and dextrose and a very great increase in the cane sugar when the potatoes are stored at low temperatures. These authors (9) have also measured the respiration of sweet potatoes during storage and have found some loss in reducing sugars through this cause. Miyaki (17), in studies upon the nature of the sugars found in sweet potatoes, concluded that the reducing sugars consisted of both

dextrose and levulose and the nonreducing sugar of sucrose. The presence of pentose, galactose, mannose, and maltose was excluded by his tests.

No reference has been found in the literature relative to the nature of the coloring substances found in sweet potatoes. The possible relation of some of these to the discoloration of the canned potato makes it of interest to know something of their nature. Qualitative tests made during the course of the present studies strongly indicated that the chief coloring substances in the flesh of the deep-colored varieties belong to the carotinoid group of chemical compounds. F. M. Schertz, of the Office of Soil-Fertility Investigations, kindly made for the writers analyses of material prepared from the Gold Skin potato and reported a finding of about 0.0073 per cent of carotin and a much smaller amount of xanthophyll. In several varieties a deep-purple pigment is present in the skin and cortex. The solubility of this pigment together with its chemical characteristics strongly indicates that it is an anthocyan, but isolation of it in pure form was not attempted. It has appeared to be associated to some extent with the discoloration of the canned potato.

The gummy latex present in the sweet potato is another substance of considerable interest. There is no published work upon its chemical nature. Carver (5) reported the preparation of a rubber compound which was probably made from some constituent of the latex. Whether there is present a true rubber hydrocarbon is not known. The latex is of interest here because in those varieties showing an abundance of it the tendency of the canned product to discolor is more pronounced. The various strains differ considerably in the apparent quantity of latex which is present.

The sweet potato as raw material for the manufacture of numerous products has received considerable attention from several workers. Carver (5) has reported, in addition to the rubber compound mentioned above, the preparation from it of starch, flour, ink, and adhesive.

Gore (6) has announced a method of preparing a palatable sirup from the sweet potato.

Mangels and Prescott (16) have reported the results of investigations upon the manufacture of sweet-potato flour by the "flake" process.

In books upon canning, the sweet potato is often spoken of and directions given for handling the product, but no comprehensive study of canning problems seems to have been made.

EXPERIMENTAL CANNING TESTS.

The experimental work upon the problem of canning sweet potatoes was begun in the fall of 1918. Surplus stocks from variety and

storage tests were made available, and work was undertaken with the view to determining what varieties were best suited for canning purposes. From preliminary investigations it soon became evident that a satisfactory comparison of the different varieties could be made only after inquiry into a number of problems which presented themselves. What should be the methods used in the preliminary handling of the potatoes before placing them in the cans? What was the nature of the discoloration which occurred, and how could it be avoided? And, from the standpoint of appearance and flavor of the product, what temperatures and time periods should be adopted in the processing of the material in the cans? These were matters which received first attention. As the work progressed new facts and conditions were brought to light, so that it was found necessary to continue the studies over a period of three successive seasons. The problems involved in the canning of sweet potatoes have by no means been exhausted, but it is felt that enough has been done to warrant the presentation of the results so far obtained. These will be considered in the order of their sequence.

WORK IN 1918.

The sweet potatoes were received at the time of or shortly after digging and were not cured. On the other hand, they were held in open crates in the floor space of a large well-ventilated building, with no attempt made to control the temperature other than to prevent freezing during the latter part of the season. Experiments were begun at once and continued up to about the middle of December.

The tendency of the material to darken on exposure to the air was encountered at the outset of the work. Examination of the potatoes showed that the cortex contained the larger part of the substance causing the darkening, and it was thought that a complete removal of the cortex would greatly diminish the trouble from this cause. Since the entire cortex could not be removed satisfactorily after cooking, it was decided to peel the potatoes before cooking. Consequently, the potatoes were peeled raw and then placed immediately in water until ready for cooking. This excluded the air from them more or less and they turned brown only after long standing in the water. Brine was tried in the place of water, but it proved only slightly more effective than the water alone. Dilute citric acid was very effective, but it gave an undesirable acid taste to the product. The following procedure seemed to offer promise of avoiding most of the difficulties, and it was temporarily adopted:

(1) Peeling the potatoes raw, after washing to remove dirt, and cutting the larger potatoes into pieces to facilitate cooking.

(2) Rinsing the potatoes in cold water, placing them at once in a steam retort, and cooking for 10 minutes at a steam pressure of 10 pounds.

(3) Placing the cooked potatoes at once into No. 3 sanitary tin cans, using a wooden plunger to pack closely and firmly.

(4) Placing cans thus filled in the cooker and steaming in flowing steam for 15 minutes.

(5) Crimping on the covers, thus tightly sealing.

(6) Processing for 70 minutes at a steam pressure of 15 pounds and cooling by placing cans in tiers on the floor of the laboratory.

The varieties and strains used in these tests included the Florida, Belmont, General Grant, White "Yam," Pierson, Miles, Early Carolina, Yellow Strasburg, Early Red Carolina, Red Brazil, Yellow "Yam," Purple "Yam," Dooley, Triumph, Porto Rico, Mullihan, Norton, Haiti, Gold Skin, Japanese "Yam," Ballinger's Pride, Big-Stem Jersey, Catawba White, Catawba Yellow, Nancy Hall, Southern Queen, and a number of unnamed strains.

Upon opening the canned material for examination the product from all the varieties was found to be quite firm. The so-called moist types were somewhat softer than the dry mealy varieties, but these differences were not very marked. As will be shown later, this was in striking contrast to the findings upon potatoes canned after curing and storage. On the basis of observations made at this time the Miles appeared to be the best among the light-colored varieties, while the Dooley, Nancy Hall, and Mullihan were best among those with deep-yellow flesh. The Early Red Carolina was best among those intermediate in color.

The necessity of a full pack and a thorough exhaust was made evident by these tests. Cans which were slack filled and processed with the others showed upon opening a marked oxidation of the exposed surface and the material immediately underlying it. Those portions from which the air was excluded remained bright, as did also that in the cans properly filled and exhausted. Upon storage the contents of those cans insufficiently exhausted became in most instances entirely black, accompanied with very marked corrosion of the cans.

Close comparison of the canning quality of the varieties could not be made from this material, since the processing, which was found too severe, had caramelized some of the sugar, causing a distinct browning in the normally light-fleshed varieties and imparting to all of them a somewhat undesirable caramel flavor. Sweet potatoes packed in glass jars and processed in boiling water for one hour on each of three successive days gave a product far superior to that just described. It was apparent, therefore, that the matter of the length and temperature of processing would have to be more thoroughly investigated before much progress could be made.

In the intermittent test just mentioned it was observed that the discoloration of the cooked potatoes when exposed to the air promptly disappeared when they were packed in glass jars, partially sealed, and processed in boiling water. Exposure to air, as when an imper-

fect seal allowed the air to enter the jar during cooling, resulted in a reappearance of the discoloration; whereas in jars in which the seal was perfect the material remained bright for an indefinite period. It was therefore apparent that peeling while raw had no advantage, and in all subsequent experiments the potatoes were cooked in the skin and peeled afterwards.

In order to determine the processing temperature and time periods which would yield the desired quality from the standpoint of appearance and flavor, the following experiments were carried out.

Potatoes of the three varieties, Nancy Hall, Big-Stem Jersey, and Southern Queen, were washed, placed on trays in a steam chamber, and subjected to flowing steam for 30 minutes. At the end of this time they were removed from the chamber, rapidly peeled by hand, and then passed through a food chopper. This gave uniform material for the tests. One lot of No. 2 and No. 3 cans of each variety was sealed at temperatures ranging from 70° to 80° C., and then another lot was allowed to cool to room temperature and then processed. From each of these lots a series of cans was treated as follows:

- (1) 1, 2, 3, 4, 5, and 6 hours continuously in boiling water.
- (2) 1½ hours in boiling water on each of three successive days.
- (3) 30, 45, 60, 75, 90, and 120 minutes in the steam retort at 109° C. (steam pressure about 5 pounds).
- (4) 30, 45, 60, 75, 90, and 120 minutes at 116° C. (steam pressure about 10 pounds).
- (5) 30, 45, 60, 75, 90, and 120 minutes at 121° C. (steam pressure about 15 pounds).

Examination of the contents of these cans showed that for the present needs the most satisfactory results could be obtained under the conditions described with No. 2 cans processed at 116° C. for 45 minutes and with No. 3 cans treated similarly for one hour. Satisfactory results as to quality were likewise obtained both by the intermittent processing in boiling water for 1½ hours and by continuous boiling in the water bath for three to four hours.

The supply of many of the varieties available for this work having been exhausted, it was impossible during this first season to carry out complete comparative tests based upon the data thus far obtained. Such material as did remain, however, was canned, and comparisons were made with that handled earlier in the season. The method of preparation of this material was essentially as described under the last experiment, special care being taken that the cans were properly filled with the hot material and sealed at once. No. 2 cans were employed and processing was done in the steam retort at 10 pounds' steam pressure for 45 minutes.

On opening these cans for the examination of the contents it was found that the potato was bright and attractive in color, no caramel-

ization was apparent to the taste or sight, and the results in general were satisfactory. Comparison of this material with that canned immediately after digging showed it to be far superior in quality, due to the first lot being overprocessed, and a marked difference in the consistency was noted. As before stated, those potatoes canned early in the season were firm and fairly dry, but in these the consistency was much less firm, and in such varieties as the Nancy Hall, Porto Rico, and Southern Queen the material was very soft and moist. The work of the earlier investigators upon the transformations in the starch of the sweet potato during storage suggested the possible cause of this difference in the consistency of freshly dug and of stored potatoes, but it was necessary to postpone investigations of this problem until some later date. All canned potatoes not already opened were stored for later comparisons.

WORK IN 1919.

The work of 1918 showed that sweet potatoes undergo changes in storage which greatly alter the firmness of the canned product and also that these changes differ with varieties. Since a rather complete record was secured upon the potatoes canned immediately after digging, it was thought advisable to get also a complete record of their canning qualities after the usual curing and storage.² For this purpose 38 varieties and strains were provided. They were dug on October 1, put into open slatted crates, and placed at once in the curing rooms. Here the temperature was maintained at about 85° F. for 10 days. At the end of this time they were transferred to the storage room, where the temperature ranged from 55° to 65° F., and were held there until used. The canning tests were made November 19 to 21.

The procedure of handling was about the same as that followed during the latter part of the preceding season. The potatoes were washed, cooked in flowing steam for 30 to 40 minutes, peeled rapidly by hand, and passed directly through a food grinder into No. 2 plain sanitary cans. Sealing was done immediately, and the temperature of the material averaged 70° to 80° C. The processing was carried out at once, one lot of each variety being given the intermittent treatment in boiling water (1½ hours on each of three successive days) and the other being processed in the steam retort at 116° C. for 45 minutes. At the end of the processing periods all cans were removed and cooled in air.

Only slight differences in quality could be noted in the material processed according to the two methods mentioned, it being judged

² For information upon curing and storing sweet potatoes, see Farmers' Bulletin 970, entitled "Sweet-Potato Storage."

that the potatoes processed intermittently in boiling water were perhaps slightly superior. The differences, however, were too slight to warrant the use of the more time-consuming and inconvenient intermittent treatment.

On November 26 a series of cans of these potatoes was opened before a committee of judges composed of representatives from the States Relations Service of the United States Department of Agriculture, the Research Laboratory of the National Cannery Association, and the Office of Horticultural and Pomological Investigations of the Bureau of Plant Industry, United States Department of Agriculture. In passing judgment upon these samples the committee was requested to consider the following points:

(1) Appearance, noting degree of color, brightness of material (or darkening if present), and general attractiveness of the product, having in mind the point of view of the housewife.

(2) Quality, noting the consistency, whether firm or soft, moist or dry, etc., the grain or texture of the product, presence of fiber, etc.

(3) Taste, noting the degree of sweetness, caramelization if evident, and distinctive flavors.

While individual opinions differed somewhat as to the qualities of the various samples, first place was unanimously awarded to the Gold Skin. Others that received favorable comment were Dooley, Porto Rico, Mullihan, Big-Stem Jersey, Yellow Jersey, Belmont, Yellow Strasburg, Early Red Carolina, Vineless Pumpkin "Yam," Dahomey, Pumpkin "Yam," and Southern Queen.

It should be remembered that this exhibit took into account only the quality of the canned product without regard to other important considerations. From the standpoint of the practical canner several matters in addition to the quality of the canned product must be taken into account, such as the yield per acre from any particular variety, the size and shape of the potatoes, and their ease of peeling.

As was to be expected, this test showed great differences in the firmness of the canned product. Some varieties, such as the Early Red Carolina and Big-Stem Jersey, were quite firm, while the Nancy Hall, Porto Rico, and some others were very soft. All degrees of firmness were represented among the varieties. This makes it apparent that, even with the cured and stored potatoes, by the selection of the proper varieties one may obtain a relatively dry firm pack or a moist one as desired, thus meeting all market demands.

Surplus stocks of these canned varieties were stored for comparison with later packs and to determine the keeping quality of the product.

Farther on in the text will be found a descriptive list of the varieties and strains of sweet potatoes used in these studies, and under each will be given a brief summary of the nature of the raw potatoes,

their yields, canning qualities, and other characters. These descriptions may be found of value in choosing the variety or varieties best suited for any particular purpose.

COMPARATIVE CANNING TESTS IN 1920.

There remained to be determined the comparative qualities of the different varieties when canned as whole potatoes, and certain of the problems connected with the canning of sweet potatoes required further investigation. Moreover, several additional varieties were made available for use. It was decided, therefore, to continue the studies for another season in order to make the work as complete as possible.

Forty-three varieties and strains were grown especially for this purpose. They were dug on October 14 and 15 and the main portion of each cured and stored, as in 1919. From the Porto Rico, Nancy Hall, Big-Stem Jersey, and Southern Queen varieties a sample was canned immediately; another at the end of 10 days' curing, when it was transferred to storage; a third sample after 10 days in storage; and a final sample after 20 days in storage. This was done to determine just what effect curing and storage have upon the canning qualities of different types of sweet potatoes. These results will be considered under the heading of "Consistency" (see page 16).

The main variety canning tests were made from November 26 to December 6. The handling of the potatoes differed from that of the 1919 season in that they were packed in two forms, as pie stock and as whole potatoes. For packing whole the potatoes were washed, the largest roots cut into smaller sizes to facilitate cooking, when necessary; placed on trays in a steam chamber; and cooked in steam at 100° C. for 30 to 40 minutes, or until done. They were peeled rapidly by hand while still very hot, a towel being used to protect the hands, the hot potatoes packed into No. 3 sanitary cans, and sealed immediately. The potatoes being very hot and the cans well filled, no exhaust was found necessary. The cans thus prepared were then processed at 116° C. for one hour, at the end of which time they were removed from the retort and cooled in air. The varieties canned as pie stock were handled as during the 1919 season, the material after passing through the food grinder going directly into No. 2 sanitary cans, then sealed at once, and processed immediately at 116° C. for 45 minutes.

On December 10 these samples of canned sweet potatoes, both in the form of pie stock and as whole potatoes, were submitted to a committee of judges, as in 1919. This committee was made up of representatives from the Research Laboratory of the National Canners' Association and of the States Relations Service, the Office of

Home Economics, and the Office of Horticultural and Pomological Investigations of the Department of Agriculture. The results of this exhibit were entirely similar to those of 1919. The Gold Skin was again unanimously awarded first place, and the Porto Rico, Nancy Hall, and Vineless Pumpkin "Yam" of the moist-fleshed group and the Big-Stem Jersey, Improved Big Stem, Yellow Strassburg, and Triumph of the firmer fleshed types, in about the order given, received favorable comment. It is almost certain that different conditions as regards time of digging, curing, and storage would have altered the results somewhat, but it is of interest to note that out of the first dozen selected as best varieties for canning six were selected both seasons.

Differences in the quality of the whole-potato product as compared with the pie stock were too small to be significant. This exhibit demonstrated again that a highly desirable canned product of either the dry firm type or the moist type may be secured even in the cured potatoes by the selection of the proper varieties.

DISCOLORATION.

The greatest difficulty encountered in the canning of sweet potatoes is to overcome the tendency of the product to discolor or darken when exposed to the air. When the raw potatoes are peeled by hand they turn brownish or dark-colored irregularly over the surface. This discoloration is much more pronounced in the region of the cortex, but it is apparent to a lesser extent throughout the potato. When the potatoes are cooked and then exposed to the air they oxidize somewhat and become darker. When exposed to the air for a few hours and then reheated in the absence of oxygen, this discoloration almost entirely disappears, but it promptly reappears on exposure to the air. There is an oxidase present in the sweet potato which would explain its behavior in the raw state, but this enzyme does not account for the discoloration after cooking, since the darkening takes place even after the exposure of the potato to a temperature of 116° C. for one hour in the autoclave. Oxygen appears to be necessary, for this darkening does not occur in cans of sweet potatoes which have been properly exhausted.

The substance which is first formed in this discoloration seems to be very unstable. It is destroyed or changed on reheating in steam, but forms again in air.

Iron or iron salts have a very marked effect upon the discoloration, causing an intensification of it and rendering it very much more permanent. Acids tend to inhibit it and alkalis to intensify it. If sections of raw sweet potato are placed in ammonia a yellowish color at first appears, which on standing becomes green. This occurs first in the cortex and may appear throughout the entire section. Lime

water, potassium hydroxid, and sodium hydroxid all give a yellowish coloration at first, which on oxidation turns brown.

If the sweet potato is cooked in steam in such a way as to eliminate the possibility of the introduction of iron, the discoloration on exposure to air is small in extent. If to some of the material cooked in this way there is added ferric chlorid, a greenish coloration is obtained. If a quantity is mixed with iron filings and exposed to the air the whole mass soon turns black. When a quantity is treated in the same way with tin or zinc no effect is noted.

Certain substances have been extracted from the sweet potato which give reactions very similar to those above described. One of the chief substances is soluble in acetone, glacial acetic acid, 70 per cent ethyl alcohol, and in water. These substances appear to be hydroxy compounds belonging to the aromatic series.

The different varieties of sweet potatoes show considerable variation in their tendency to discolor. The Jersey group, including the Gold Skin, Big-Stem Jersey, and Early Red Carolina, show it the least of those tested, and members of the Spanish group, including the Triumph and the deeply pigmented varieties, such as the Purple "Yam," Japanese "Yam," and Dahomey, show it the most. It would seem that there might be some correlation between this pigment and the discoloration. All the varieties and strains here tested have shown these phenomena to a greater or less extent. In the light-fleshed individuals the discoloration is more apparent than in the more deeply colored varieties, though this may be due to the partial masking of it by the deep-yellow color.

If in packing sweet potatoes the cans are sealed without exhausting—that is, if air is left in the can—the product will darken. After some time in storage the metal of the container becomes badly corroded and the potato contained in it turns black. This darkening begins at the top of the can; that is, the portion exposed to the air in the can turns brown and those portions exposed to both the air and the metal of the can turn black.

However, as the oxygen and the iron become diffused into the material the whole becomes black. Those portions in actual contact with the metal of the cans, if the air is excluded, remain bright throughout. These findings are entirely contradictory to the report of Kohman (14), in which it is stated that the darkening begins at the bottom of the can where the material is in direct contact with the metal of the container. If the can is filled quite full with the potatoes at a temperature of 80° C. or above, sealed immediately, and processed, very little action upon the metal of the container is apparent and the material remains bright. The writers have kept cans of sweet potatoes handled in this way for three years under ordinary storage conditions with no discoloration taking place.

Numerous experiments were made to see whether the tendency to darken could be prevented by treatment of the potatoes with different substances. Acetic, tartaric, and sulphurous acids were found to reduce the extent of the discoloration to a minimum, but they gave an undesirable flavor to the product. Sodium chlorid in various concentrations was also tried. It was found that if whole sweet potatoes were placed in the can without packing closely and a 10 per cent salt solution was added to fill the air spaces, the discoloration was prevented. Water alone was just as effective in so far as it excluded the oxygen from the material. Some tests were made by dipping the potatoes in a 10 per cent salt solution and then filling into the can. It did not prevent discoloration in the presence of oxygen. Campbell (4) states that discoloration may be prevented by the use of sodium chlorid, but in these tests the salt was not effective if the exhaust was insufficient, and when the exhaust was sufficient no salt was necessary. Proper exhausting is likewise essential to prevent the loss of the bright orange or yellow color which occurs when the carotinoids that give this color are oxidized in the presence of air.

The most effective way of preventing discoloration in the can and preserving the natural bright color is to handle the potatoes so that the material after cooking is exposed to the air for the shortest possible time, filling the potatoes into the can at a temperature not below 70° C., filling the can so that there is but a very small head space, and sealing at once.

Sweet potatoes which have been properly handled during the canning operations will usually darken somewhat on exposure to the air, though ordinarily this is not sufficient to be objectionable. The amount of this discoloration depends largely upon the particular variety of potato used and especially upon the length of time the canned product has been held in storage. During these studies it was repeatedly demonstrated that whereas the canned potatoes opened and exposed to the air 10 days after packing showed discoloration on standing, the same varieties handled in the same way when opened one year after packing remained bright. This was found to hold true for all the varieties tested, but the explanation of the phenomenon can not yet be given. This fact may be of considerable practical significance.

Of particular importance is the relation of sweet-potato diseases to discoloration. Even in potatoes which are only slightly affected by fungous disease the tendency to darken is very greatly increased, and discoloration can scarcely be prevented in such material. Moreover, the discoloration arising from this cause is more permanent and can not be destroyed by any simple means. In the canned product the affected portions become brown or black in color and give a very undesirable appearance to the potatoes. In canning practice, therefore, all affected tissue must be carefully and completely removed. It has

been found necessary even to remove considerable tissue in advance of the fungous growth.

There is another type of discoloration met with in the canning of sweet potatoes which is due to the influence of heat. At very high temperatures, even in well-exhausted cans, the potatoes turn reddish brown in color; but it is more marked if oxygen is present. The condition is due to carmelization of the sugars and to changes in other constituents of the product. It is also accompanied by an alteration of flavor. Discoloration of this type is easily avoided by carefully adjusting the time and temperature of processing.

HEAT PENETRATION AND STERILIZATION.

The rate of temperature changes in sweet potatoes during canning and the influence which initial temperatures have upon it have been fully considered by the writers in United States Department of Agriculture Bulletins Nos. 956 and 1022. Extended discussion of it here, therefore, is unnecessary. Sweet potatoes have a heavy consistency, and the penetration of heat into a can of such material is very slow. If the potatoes are introduced into the can after they have cooled considerably a much longer time is required for processing and the danger of spoilage is increased. For the same reason short heating in the exhaust box is ineffective in producing a proper vacuum. No attempt was made in these studies to determine the processing temperatures and time periods necessary to effect complete sterilization. Though the statement of Weinzirl (20) that the sweet potato offers an unusual test of sterilization would lead one to think that it is very difficult to can successfully, three years of observation and study of sweet-potato canning lead the writers to the conclusion that this product is very easily preserved. Rigorous processing, such as is demanded by some of our standard food products, seems not to be essential to satisfactory results with sweet potatoes. Packing the potatoes into the cans at a temperature not below 70° C. and processing at 116° C. for a length of time sufficient to bring the material at the center of the can somewhat above 100° C. has given uniformly good results in the work here recorded.

Differences in the rate of heat penetration in the "dry" firm varieties and in those which are soft and "moist" have been found too slight to be of any practical significance. Modifications in the processing due to any varietal differences in potatoes, therefore, appear unnecessary.

CONSISTENCY.

The behavior of different varieties of sweet potatoes on cooking is extremely variable. Some remain quite dry and mealy and are firm

in consistency, while others become very soft and moist. Their behavior in canning is entirely similar.

The first season in which these studies were carried on the canning of the potatoes was done shortly after digging. All the varieties studied gave a product which was quite firm, though the representatives of the Jersey group were somewhat firmer than those of the other groups. The Vineless Pumpkin "Yam" and one or two others were considerably less firm. The following season the potatoes were cured after digging and then placed in storage for a time before the canning tests were made, and the results obtained were very different. All were sweeter and somewhat softer in consistency than those canned the preceding year. The Nancy Hall, Dooley, Porto Rico, and Vineless Pumpkin "Yam" yielded a very soft moist product; many others were of medium consistency, and a few, including the Big-Stem Jersey, Early Red Carolina, and Gold Skin, remained relatively firm. This matter of firmness or softness of a variety on cooking is held of much importance, because the soft moist type is in greatest favor in the South while the dry firm type has been considered most desirable for the northern market. Since the work of the two preceding years had shown that the varieties differed among themselves with respect to this property and that changes also occurred after digging, the extent of which differed with varieties, it was thought advisable to make a somewhat more detailed study, in order to determine the amount and rate of these changes and their effect upon the quality of the canned potatoes.

It was impracticable to carry on such a detailed study of all of the forty-odd varieties and strains under investigation, so the third season four representatives were chosen from the list for this work. The others were cured, stored, and canned as previously set forth. In addition to their use for comparative-quality judging and for exhibition purposes these were all submitted to consistency tests made according to the method which will be described presently in the consideration of the four selected varieties. The results of these tests will be found in a later table.

The four varieties used in the detailed studies were Big-Stem Jersey, Southern Queen, Porto Rico, and Nancy Hall. The Big-Stem Jersey was selected as the representative of the dry, firm group, the Porto Rico and Nancy Hall as representatives of the soft, moist varieties, and the Southern Queen as representative of the intermediate group. One lot from each of these varieties was canned immediately after digging; another after curing for 10 days at the average temperature of about 85° F.; a third lot after 10 days in storage at 55° to 60° F. following curing; and a fourth lot after 20 days in storage. Representative cans for each stage in the handling of the

four varieties were opened and physical tests made to determine their relative plasticity.

Not having available a suitable plastometer, the resistance of the material to pressure was measured by a simple device constructed and employed as follows: To the upper end of a plunger made from a piece of polished brass rod half a square centimeter in cross section a small weight pan of sheet tin was attached by means of a drop of solder. At just 2 centimeters from the other end of the plunger, which was carefully squared off perpendicularly to the axis, a file mark was made. This plunger, which was held in a vertical position by a glass sleeve supported in a ring stand clamp, was so arranged that the test can of material could be placed under it and the end of the plunger lowered to the surface of the material.

To carry out the test the entire end of the can was removed, the plunger lowered to the surface of the test material, and weights added to the weight pan until the plunger penetrated the material. The sum of all the weights (weight of the plunger plus the added weights), expressed in grams, required to push the plunger into the test material up to the file mark in just 1 minute was taken as the factor expressing the relative plasticity of the samples. Table 2 gives the figures thus obtained. They represent averages of many tests made upon both ends of the cans of material tested.

TABLE 2.—*Relative plasticity of sweet potatoes canned in the form of pie stock during the various stages of handling.*

Variety.	Plasticity factor (grams).			
	After curing for 10 days at 85°F.			
	Freshly dug.	No storage period.	Subsequent period of storage at 55° to 65° F.	
			10 days.	20 days.
Big-Stem Jersey.....	230	94	87	85
Southern Queen.....	92	71	34	20
Nancy Hall.....	104	30	22	17
Porto Rico.....	216	20	25	31

From the above it will be seen that at the time of digging all four varieties gave a relatively firm product. The Big-Stem Jersey and Porto Rico were especially firm. The Nancy Hall was somewhat softer, but still quite firm, while the Southern Queen ranked slightly lower. The figures obtained at the other stages of handling are very interesting. After curing, the Big-Stem Jersey lost much of its firmness but was still quite resistant to penetration. During the storage period there was a slight gradual decline, but this was not

sufficient to alter the plasticity to any marked extent. The Southern Queen changed less rapidly than any of the others during curing, but lost its firmness rapidly in storage, arriving at the end of the test period in a very soft condition. Very marked changes took place in the Nancy Hall and the Porto Rico during the curing period. At the end of this time both were very soft. A continuous loss in the case of the Nancy Hall and a slight increase in the Porto Rico are noted, but they have no practical significance probably, as both varieties had become very soft.

All the different potatoes studied have been found to vary in somewhat the same way, as is shown in the examples just given. Though, as has been pointed out, some variations have been noted in the consistency at the time of digging, all when freshly dug yield a comparatively firm product. Table 3 shows the results of consistency tests upon these varieties made after curing and storage. The tests were carried out in the same manner as in the tests just described. The varieties are arranged in the order of their firmness as found in these tests.

TABLE 3.—*Relative plasticity of different varieties of sweet potatoes canned in the form of pie stock after curing and storage.*

Variety.	Grams.	Variety.	Grams.	Variety.	Grams.
Early Red Carolina.....	210	No. 11284.....	75	No. 39833.....	42
No. 11286.....	172	Triumph.....	71	Key West.....	35
Big-Stem Jersey.....	158	No. 10650.....	68	Miles.....	34
Red Jersey.....	137	Pierson.....	64	Dooley.....	34
No. 7980.....	125	Florida.....	62	Southern Queen.....	30
Yellow Jersey.....	108	Early Carolina.....	60	Ballinger's Pride.....	30
Yellow Strasburg.....	105	Gros Grandia.....	60	Golden Beauty.....	29
Improved Big Stem.....	105	Mullihan.....	58	White "Yam".....	29
General Grant.....	97	Red Brazil.....	52	Creola.....	28
No. 10412.....	95	Red Bermuda.....	50	Porto Rico.....	28
Dahomey.....	89	Catawba White.....	50	Vineless Pumpkin	
Catawba Yellow.....	85	Yellow Belmont.....	46	"Yam".....	25
Gold Skin.....	82	No. 11285.....	45	Nancy Hall.....	20
Haiti.....	81	Vineless.....	45		
No. 49711.....	78	No. 22437.....	45		

It will be seen that after curing and storage the plasticity varies all the way from quite firm to very soft, all degrees of plasticity being found.

These observed changes in consistency during curing and storage at once raised the question as to the cause, and the samples were submitted to chemical analysis to determine what substances were involved. The analyses were carried out in the following way: Duplicate samples of 100 grams were weighed out from the thoroughly mixed material and enough 95 per cent alcohol added to give an 80 per cent mixture. This was thoroughly stirred, and after standing for several hours the alcohol was decanted through an extraction cup into a flask and more 95 per cent alcohol added to the material. This was repeated three or four times. After decanting for the last time

the residue was transferred to the extraction cup and the extraction completed in a Soxhlet. The greater part of the extraction, therefore, was done in the cold, and the Soxhlet cup was used merely to remove the last traces of sugars. This procedure eliminated as far as possible any change during extraction.

Determination of sugars in the extract was made according to the methods of the Association of Official Agricultural Chemists, and the total polysaccharids in the residue were also determined by these methods.

It seemed desirable to know something of the nature of the polysaccharid content. In preliminary tests the residues from the firm lots gave a blue color with iodine, while the residues from the soft samples gave a red color. This seemed to indicate the presence of dextrin in the latter samples and suggested that the plasticity of the canned sweet potato might depend on whether starch or dextrin was present. The observation appeared so significant that further tests were made to determine more definitely the identity of the substance. It was found to be precipitated by alcohol; upon hydrolysis it yielded reducing sugars; it was not precipitated by basic lead acetate, gave a red coloration with iodine, and possessed adhesive properties. It was evident, therefore, that during cooking the starch had been gelatinized and that insoluble starch, soluble starch, and dextrin possibly existed in various proportions in the samples. An effort was then made to determine the amount of dextrin present.

There was no very satisfactory method for the determination of dextrin in the presence of soluble starch, but the following method was finally adopted for its estimation: 1 gram of the dried residue from the extraction was ground thoroughly with 10 to 15 c. c. of distilled water. After grinding, more water was added and the whole transferred to a 100 c. c. volumetric flask. The volume was brought to about 90 c. c. and the solution allowed to stand for 30 minutes with frequent shaking. At the end of this time 2 c. c. of a basic lead-acetate solution was added to precipitate the soluble starch and the volume then made up to 100 c. c. After shaking thoroughly it was passed through a dry filter and the rotation of the filtrate taken. The determination of dextrin from the polariscope readings was calculated by the formula given by Browne (3). It must be understood that the figures obtained are but rough approximations of the real dextrin content of the samples. For making the polariscope readings and assisting in the interpretation of the results the writers are indebted to Dr. S. F. Sherwood, of the Office of Sugar-Plant Investigations.

Table 4 shows the results of the chemical analyses of samples of four varieties of sweet potatoes canned at intervals of 10 days during curing and storage.

TABLE 4.—*Results of chemical analyses of samples of four varieties of sweet potatoes canned at intervals of 10 days during curing and storage.*

Sample.	Constituents (per cent).						Dextrin.
	Mois- ture.	Dry weight.	Sugar content (calculated as invert).			Total polysac- charids (calcu- lated as starch).	
			Reducing (before in- version).	Nonre- ducing.	Total.		
Big-Stem Jersey:							
Freshly dug	72.63	27.37	6.50	2.15	8.65	10.85	0
After curing 10 days	71.51	28.49	5.65	4.15	9.80	10.31	0.41
After storage—							
10 days	71.23	28.77	6.03	4.59	10.62	10.39	.....
20 days	70.40	29.60	6.11	4.51	10.62	10.36	.46
Nancy Hall:							
Freshly dug	66.80	33.20	9.17	1.89	11.06	11.02	.32
After curing 10 days	66.80	33.20	9.76	4.23	13.99	8.51	4.78
After storage—							
10 days	64.60	35.40	10.57	4.51	15.08	9.21	5.18
20 days	65.11	34.89	10.38	4.65	15.03	9.14	5.11
Southern Queen:							
Freshly dug	71.09	28.91	7.67	1.38	9.05	10.64	.17
After curing 10 days	68.62	31.38	8.18	3.74	11.92	9.53	1.33
After storage—							
10 days	68.55	31.45	9.08	3.02	12.10	10.14	4.73
20 days	68.57	31.43	8.39	3.70	12.09	9.06	3.78
Porto Rico:							
Freshly dug	70.03	29.97	6.75	1.83	8.58	11.06	0
After curing 10 days	69.15	30.85	8.90	4.88	13.78	7.65	3.92
After storage—							
10 days	68.78	31.22	8.29	5.34	13.63	8.44	3.88
20 days	68.20	31.80	8.86	4.88	13.74	9.13	3.66

From Table 4 it will be seen that the moisture content of the canned product is highest in the lots canned immediately after digging, those canned at the end of the storage period of 20 days showing a loss of from 1.6 to 2.5 per cent. The total sugar content increases in the succeeding tests and the total polysaccharids, calculated as starch, decrease, but these changes seem insufficient to account for the enormous change in plasticity.

The dextrin content of the samples is of interest. In the Big-Stem Jersey none was found in the material canned from freshly dug potatoes, and only a relatively small amount in any of the lots canned subsequently. In the Nancy Hall there was a small amount of dextrin in the material from the freshly dug potatoes and this quantity greatly increased in the material from the cured and from the stored potatoes. The Southern Queen showed a small dextrin content in the lot from the freshly dug roots, a larger amount in material cured for 10 days, though less than is formed in the corresponding lots of Nancy Hall and Porto Rico, and a considerable amount in the lots from stored potatoes. The figures for the Porto Rico are similar to those for the Nancy Hall except that no dextrin is found in material from the freshly dug potatoes and the figures in the succeeding lots are somewhat lower. From qualitative tests made in connection with these studies but not recorded here it seems almost certain that

the percentage of dextrin is considerably higher than the figures indicate.

These figures are of especial significance when they are correlated with those for the plasticity of samples given in Table 2. The marked increase in dextrin content corresponds exactly in point of its appearance with the softening of the potato. In the Nancy Hall and Porto Rico this occurs after 10 days' curing of the potatoes, while in the Southern Queen the marked increase is found in the lot canned after 10 days' storage following curing. The marked firmness of the Big-Stem Jersey canned at the end of 20 days of storage likewise coincides with the low dextrin content found. Considering the fact that both in the determination of the plasticity and in the determination of the dextrin the methods used were crude, the relatively close correlation of the two sets of figures appears significant.

Samples of the Porto Rico variety canned immediately after digging gave a blue coloration with iodine, characteristic of starch, but the same variety after 10 days of curing gave a reddish color with iodine. The Big-Stem Jersey, on the other hand, gave a blue coloration with iodine at each of the stages of curing and storage. It seems, therefore, that after cooking the soft potatoes contain dextrin instead of starch as the chief polysaccharide, while the firmer ones contain starch largely. It appears, therefore, that the plasticity of the sweet potato after cooking is dependent upon the ratio of starch to water present. During curing and storage, transformations take place which on cooking result in the change of starch to variable proportions of sugar, dextrin, and probably all the intermediate products, depending upon the particular variety of sweet potato used.

This work suggests that the differences in the cooking quality of varieties of the Irish potato may be due to causes of a similar nature.

In making sweet-potato flour by the flake process Mangels and Prescott (16) state that there developed hygroscopic and gummy substances which interfered with the success of the process. These workers used the Porto Rico, Nancy Hall, and Southern Queen varieties, and the experiments were made in the late winter. Their results are not surprising, therefore, for their material must certainly have contained a large percentage of dextrin. The chances of success would have been much better if the firm-fleshed varieties or freshly dug potatoes had been used.

It is shown by these tests that in some varieties the changes that cause the loss of firmness occur rather quickly after digging. At this point attention should be drawn perhaps to the fact brought out in the work of some of the earlier investigators (12) that changes occurring in sweet potatoes begin to some extent even before digging. It is probable, therefore, that the firmness varies somewhat with

the time of digging. It has not been possible for the writers as yet to test the different varieties in this respect.

In considering the table qualities of the sweet potatoes canned immediately after digging and of those canned after the usual curing and storage, preferences, so far as it has been possible to obtain them, seem to favor the latter, since in the curing and subsequent storage the sweetness increases and the distinctive flavors become more fully developed. For certain culinary uses, however, the firmer product from the freshly dug potatoes would be more adaptable; and those persons favoring a dry potato would doubtless find that the physical qualities obtained would more than offset the added sweetness and flavor.

When canned after curing and storage, the soft-fleshed varieties, like the Nancy Hall, Porto Rico, etc., yield during the canning process a liquid which is quite sweet. This is what gives to these varieties their moist appearance. The presence of this liquid does not signify a high moisture content, however, for in these varieties the moisture may be actually lower than in that of the Big-Stem Jersey and others of the firm types. The proportion of starch present seems to account largely for this condition.

VARIETIES AND STRAINS OF SWEET POTATOES USED IN THESE TESTS.

The following brief descriptive list of the varieties and strains of sweet potatoes used in these studies is given not for its taxonomic value but to assist the practical worker in the selection of suitable varieties to meet particular needs. Those interested in the classification of the sweet-potato varieties should consult the work of Thompson and Beattie (19).

The statements regarding vine and root characters are based upon the work of the above authors, confirmed by field observations. The productiveness of varieties and strains is indicated by terms descriptive of results obtained at the Arlington Experimental Farm, it being recognized that yields vary considerably under different climatic and soil conditions.

The terms defining the color of the skin, flesh, and cooked potato are taken from the work of Ridgway,³ with the colored plates of which the writers have made direct comparisons. Skin colors may vary with different soils. The colored plates found at the end of this bulletin (Pls. I to III) show the shades of color of the canned product of the different varieties here listed.

Firmness and softness of the canned product have been graded under the heads "very firm," "firm," "medium firm," "medium

³ Ridgway, Robert. Color Standards and Color Nomenclature. 43 p., 53 pl. (col.). Washington, D. C. 1912.

soft," "soft," and "very soft." An idea of the values attached to these grades may be gained by taking the product of the freshly dug Big-Stem Jersey as "very firm" and that of the cured and stored Nancy Hall as "very soft."

The "peeling quality" indicates the relative ease with which the cooked potatoes are peeled by hand.

The quality of the canned product is graded as "very good," "good," "fair," "poor," and "very poor," which terms are self-explanatory. The canning quality ascribed to the varieties and strains is based upon the results of comparative canning tests and quality judging for three seasons.

Certain potatoes in the list bear numbers only. These are unnamed strains under study at the Arlington Experimental Farm which were canned along with the named varieties.

DESCRIPTIVE LIST.

Ballinger's Pride (a strain of Southern Queen). Vines large and vigorous, long, 6 to 12 feet. Roots medium to large in size, fusiform, smooth, and regular. Yields, medium heavy. Color of skin, cream color. Color of flesh, massicot yellow to ivory yellow. Peeling quality, poor. Color of cooked potato, empire yellow to apricot yellow (Pl. I, fig. 1). Consistency of freshly dug potatoes, firm. Consistency after curing and storage, very soft. Tendency to darken, pronounced. Canning quality, fair.

Belmont. Vines low, long trailing. Roots medium in size, fusiform in shape, smooth. Color of skin, cream buff, frequently mottled with pinkish buff. Color of flesh, uniform ivory yellow. Cortex splashed with flesh color. Peeling quality, fair to good. Color of cooked potato, apricot yellow (Pl. I, fig. 2). Consistency of freshly dug potato, firm. Consistency after curing and storage, medium soft. Tendency to darken, rather pronounced. Canning quality, poor to fair.

Big-Stem Jersey. Vines moderately large growing, long, 6 to 12 feet. Roots small to large in size, long fusiform in shape, smooth or veined, regular. Yields, medium heavy. Color of skin, cinnamon buff. Color of flesh, amber yellow to straw yellow, mottled with flesh color. Peeling quality, fair to poor. Color of cooked potato, deep chrome to apricot yellow (Pl. I, fig. 3). Consistency of freshly dug potato, very firm. Consistency after curing and storage, firm. Tendency to darken, little. Canning quality, good.

Catawba White (a strain of Southern Queen). Vines large and vigorous, long, 6 to 12 feet. Roots medium to large in size, fusiform, globoid or ovoid in shape, smooth and regular. Yields, light to medium. Color of skin, cream buff. Color of flesh, ivory yellow. Peeling quality, fair. Color of cooked potato, apricot yellow to light orange yellow (Pl. I, fig. 4). Consistency of freshly dug potato, firm. Consistency after curing and storage, medium soft. Tendency to darken, pronounced. Canning quality, fair.

Catawba Yellow (a strain of Southern Queen). Vines large and vigorous, long, 6 to 12 feet. Roots medium to large in size, fusiform, globular or ovoid in shape, smooth and regular. Yields, light. Color of skin, cream buff. Color of flesh, fairly uniform ivory yellow. Peeling quality, fair. Color of cooked potato, empire yellow (Pl. I, fig. 5). Consistency of freshly dug potato, firm. Consistency after curing and storage, medium firm. Tendency to darken, pronounced. Canning quality, fair.

- Creola.** Vines vigorous, long to very long, 8 to 20 feet. Roots medium to large in size, oblong to fusiform in shape, regular and smooth. Yields, medium heavy. Color of skin, flesh color to salmon color. Color of flesh, uniformly straw yellow. Peeling quality, good. Color of cooked potato, apricot yellow to empire yellow (Pl. I, fig. 6). Consistency of freshly dug potatoes, medium firm. Consistency after curing and storage, very soft. Tendency to darken, little. Canning quality, fair.
- Dahomey.** Vines medium to long, 6 to 10 feet. Roots long cylindrical in shape. Yields, medium heavy. Color of skin, neutral red. Color of flesh, marguerite yellow. Peeling quality, poor. Color of cooked potato, straw yellow (Pl. I, fig. 7). Consistency of freshly dug potatoes, firm. Consistency after curing and storage, medium firm. Tendency to darken, pronounced. Canning quality, fair.
- Dooley.** Vines long to very long, 10 to 15 feet. Roots large in circumference, short fusiform in shape. Yields, heavy. Color of skin, light ochraceous buff with cream-buff veins. Color of flesh, flesh color interspersed with straw yellow. Cortex, ochraceous salmon. Peeling quality, good. Color of cooked potato, orange (Pl. I, fig. 8). Consistency of freshly dug potato, firm to medium firm. Consistency after curing and storage, soft to very soft. Tendency to darken, little. Canning quality, good.
- Early Carolina** (a strain of Yellow Jersey). Vines medium long trailing. Roots medium in size, fusiform in shape, regular. Yields, medium heavy. Color of skin, cinnamon buff. Color of flesh, colonial buff with considerable salmon color especially prominent near the cortex. Peeling quality, good. Color of cooked potato, empire yellow to apricot yellow (Pl. I, fig. 9). Consistency of freshly dug potato, firm. Consistency after curing and storage, medium firm. Tendency to darken, pronounced. Canning quality, fair.
- Early Red Carolina** (probably same as Red Jersey). Vines medium long, low trailing. Roots medium to small, fusiform to globoid in shape, smooth and regular. Yields, medium heavy. Color of skin, deep Corinthian red. Color of flesh, massicot yellow, with small areas of flesh color. Somewhat variable. Peeling quality, rather poor. Color of cooked potato, apricot yellow to empire yellow (Pl. I, fig. 10). Consistency of freshly dug potato, very firm. Consistency after curing and storage, firm. Tendency to darken, little. Canning quality, good.
- Florida.** Vines large, vigorous, medium in length, 4 to 9 feet. Roots medium in size, long fusiform in shape, fairly smooth and regular. Yields, medium heavy. Peeling quality, poor. Color of cooked potato, buff yellow (Pl. I, fig. 11). Consistency of freshly dug potatoes, firm. Consistency after curing and storage, medium firm. Tendency to darken, pronounced. Canning quality, poor.
- General Grant.** Vines medium to large, vigorous, medium in length, 4 to 10 feet. Roots medium in size, short fusiform to long fusiform in shape, smooth and regular. Yields, light to medium. Color of skin, cream buff frequently mottled with pale cinnamon pink. Color of flesh, flesh to straw yellow grading to almost white, mottled with pale cinnamon pink. Peeling quality, poor. Color of cooked potato, buff yellow (Pl. I, fig. 12). Consistency of freshly dug potato, firm. Consistency after curing and storage, medium firm. Tendency to darken, pronounced. Canning quality, poor.
- Golden Beauty** (same as Porto Rico). Vines vigorous, medium long, spreading. Roots medium to large in size, fusiform to globular and irregular in shape, smooth. Yields, heavy. Color of skin, flesh color to Japan rose. Color

of flesh, carrot red to flesh color, irregularly mixed with buff yellow. Peeling quality, good. Color of cooked potato, orange (Pl. I, fig. 13). Consistency of freshly dug potato, very firm. Consistency after curing and storage, very soft. Tendency to darken, little. Canning quality, very good.

Gold Skin. Vines medium to long, slender, 6 to 10 feet. Roots, small to medium, fusiform in shape, smooth and regular. Yields, medium to heavy. Color of skin, ochraceous buff. Color of flesh, salmon buff with streaks of straw yellow. Cortex, maize yellow. Peeling quality, good. Color of cooked potato, deep chrome (Pl. I, fig. 14). Consistency of freshly dug potatoes, very firm. Consistency after curing and storage, medium firm. Tendency to darken, little or none. Canning quality, very good.

Gros Grandia. Vines short to vineless, 1½ to 3 feet, stems very coarse. Roots cylindrical, veins slightly raised. Yields, light to medium. Color of skin, light Corinthian red to dark vinaceous. Color of flesh, almost white. Peeling quality, good. Color of cooked potato, cream (Pl. I, fig. 15). Consistency of freshly dug potatoes, firm. Consistency after curing and storage, medium firm. Tendency to darken, pronounced. Canning quality, poor.

Haiti. Vines quite vigorous, spreading. Roots medium to very large in size, irregular, grooved. Yields, medium to heavy. Color of skin, deep hellebore red. Color of flesh, ivory yellow with traces of flesh color. Peeling quality, good. Color of cooked potato, empire yellow to apricot yellow (Pl. II, fig. 1). Consistency of freshly dug potatoes, firm. Consistency after curing and storage, medium firm. Tendency to darken, little. Canning quality, fair.

Improved Big Stem (same as Big-Stem Jersey). Vines medium vigorous, long, low trailing. Roots medium in size, fusiform in shape. Yields, medium heavy. Color of skin, cinnamon buff. Color of flesh, amber yellow to straw yellow, mottled with flesh color. Somewhat variable. Peeling quality, poor. Color of cooked potato, empire yellow to apricot yellow (Pl. II, fig. 2). Consistency of freshly dug potatoes, very firm. Consistency after curing and storage, firm. Tendency to darken, pronounced. Canning quality, fair to good.

Japanese "Yam." Vines vigorous, medium long. Roots elongated, cylindrical, irregular. Yields, medium heavy. Color of skin, deep hellebore red to neutral red. Color of flesh, fairly uniform ivory yellow. Peeling quality, good. Color of cooked potato, amber yellow (Pl. II, fig. 3). Consistency of freshly dug potato, firm to medium firm. Consistency after curing and storage, soft. Tendency to darken, pronounced. Canning quality, poor to fair.

Key West. Vines medium to long, 4 to 10 feet, stems coarse. Roots medium to large, medium to long, cylindrical in shape. Yields, medium to heavy. Color of skin, buff pink, slightly deeper around the eyes. Color of flesh, straw yellow. Peeling quality, fair. Color of cooked potato, apricot yellow to empire yellow (Pl. II, fig. 4). Consistency of freshly dug potatoes, medium firm. Consistency after curing and storage, soft. Tendency to darken, pronounced. Canning quality, fair.

Miles (a strain of Southern Queen). Vines vigorous, rather coarse. Roots medium sized, fusiform in shape, smooth and regular. Yields heavy. Color of skin, massicot yellow. Color of flesh, massicot yellow grading to nearly white. Peeling quality, poor. Color of cooked potato, empire yellow to apricot yellow (Pl. II, fig. 5). Consistency of freshly dug potatoes, firm to medium firm. Consistency after curing and storage, soft. Tendency to darken, pronounced. Canning quality, fair.

- Mullihan** (a strain of Nancy Hall). Vines vigorous, stems rather coarse. Roots medium sized, fusiform in shape, smooth, regular. Color of skin, warm buff more or less suffused with light ochraceous salmon. Color of flesh, straw color intermixed with flesh color. Peeling quality, good. Color of cooked potato, cadmium yellow to capucine yellow (Pl. II, fig. 6). Consistency of freshly dug potato, firm. Consistency after curing and storage, soft. Tendency to darken, little. Canning quality, good.
- Nancy Hall.** Vines medium in length, vigorous, 4 to 8 feet. Roots medium to large in size, fusiform in shape, veined or smooth and regular. Yields heavy. Color of skin, warm buff, more or less suffused with light ochraceous salmon. Color of flesh, straw color intermixed with flesh color. Peeling quality, good. Color of cooked potato, cadmium yellow to capucine yellow (Pl. II, fig. 7). Consistency of freshly dug potato, firm. Consistency after curing and storage, very soft. Tendency to darken, little. Canning quality, good.
- Pierson.** Vines large, vigorous, long creeping, 6 to 15 feet. Roots medium to very large in size, fusiform and ovoid in shape, strongly ribbed and veined, very rough. Yields heavy. Color of skin, cream buff. Color of flesh, colonial buff to massicot yellow. Peeling quality, poor. Color of cooked potato, apricot yellow to empire yellow (Pl. II, fig. 8). Consistency of freshly dug potatoes, medium firm to firm. Consistency after curing and storage, medium firm. Tendency to darken, pronounced. Canning quality, poor.
- Porto Rico.** Vines medium to long, 5 to 10 feet, stems coarse. Roots medium to large in size, fusiform to globular and irregular in shape, smooth. Yields heavy. Color of skin, flesh color to Japan rose. Color of flesh, carrot red to flesh color, irregularly mixed with buff yellow. Peeling quality, good. Color of cooked potato, orange (Pl. II, fig. 9). Consistency of freshly dug potatoes, firm to very firm. Consistency after curing and storage, very soft. Tendency to darken, little. Canning quality, very good.
- Pumpkin "Yam."** Vines moderately large growing, long, 6 to 12 feet. Roots medium in size, fusiform in shape, mostly regular with few veins. Yields, medium to heavy. Color of skin, pinkish cinnamon. Color of flesh, carrot red to salmon color with irregular areas of ivory yellow. Peeling quality, good. Color of cooked potato, orange (Pl. II, fig. 10). Consistency of freshly dug potatoes, firm to medium firm. Consistency after curing and storage, very soft. Tendency to darken, little. Canning quality, good.
- Purple "Yam" ("Nigger Choker").** Vines long and vigorous, 5 to 16 feet. Roots long cylindrical, regular or irregular in shape, medium to large in size, smooth. Yields, medium heavy. Color of skin, neutral red. Color of flesh, almost white with occasional magenta purple stains. Cortex, dull magenta purple. Peeling quality, poor. Color of cooked potato, cream buff. (Pl. II, fig. 11). Consistency of freshly dug potatoes, very firm. Consistency after curing and storage, firm. Tendency to darken, very pronounced. Canning quality, poor.
- Red Bermuda.** Vines large and vigorous, long creeping, 6 to 12 feet. Roots medium to large, short fusiform, globular, or ovoid in shape, irregular, and strongly ribbed and veined. Yields heavy. Color of skin, irregular, principally Indian lake with warm buff interspersed. Color of flesh, cream. Peeling quality, fair. Color of cooked potato, empire yellow to apricot yellow (Pl. II, fig. 12). Consistency of freshly dug potatoes, firm. Consistency after curing and storage, medium firm. Tendency to darken, pronounced. Canning quality, fair to good.

Red Brazil. Vines long to very long, 6 to 20 feet, vigorous, stems medium coarse. Roots large, globular, ribbed and irregular, surface smooth. Color of skin, light Corinthian red. Color of flesh, massicot yellow. Cortex, colonial buff. Peeling quality, good. Color of cooked potato, empire yellow to apricot yellow (Pl. II, fig. 13). Consistency of freshly dug potatoes, firm. Consistency after curing and storage, medium firm. Tendency to darken, pronounced. Canning quality, fair to good.

Red Jersey. Vines long, medium vigorous, low trailing. Roots medium to small, fusiform in shape, regular and smooth. Yields, medium heavy. Color of skin, Indian lake. Color of flesh, cream with areas of mustard yellow, especially below cortex, and small stains of carrot red. Somewhat variable. Peeling quality, fair. Color of cooked potato, apricot yellow to empire yellow (Pl. II, fig. 14). Consistency of freshly dug potatoes, very firm. Consistency after curing and storage, firm. Tendency to darken, little. Canning quality, good.

Southern Queen. Vines large and vigorous, 6 to 12 feet. Roots medium to large, fusiform globular, or ovoid in shape, somewhat veined or smooth, regular. Yields heavy. Color of skin, cream buff, frequently mottled with pale cinnamon pink. Color of flesh, massicot yellow. Peeling quality, fair. Color of cooked potato, apricot yellow to empire yellow (Pl. II, fig. 15). Consistency of freshly dug potatoes, firm to medium firm. Consistency after curing and storage, soft. Tendency to darken, pronounced. Canning quality, fair.

Triumph. Vines coarse and vigorous, short, 2 to 4 feet, bushy. Roots medium to large in size, medium to long cylindrical in shape. Yields heavy. Color of skin, chamois. Color of flesh, uniform ivory yellow. Peeling quality, good. Color of cooked potato, pinard yellow to buff yellow (Pl. III, fig. 1). Consistency of freshly dug potatoes, firm. Consistency after curing and storage, medium firm. Tendency to darken, little. Canning quality, fair to good.

Vineless Pumpkin "Yam." Vines medium in length, 4 to 8 feet. Roots medium in size, fusiform to ovoid or cylindrical in shape with few low veins. Yields, medium heavy. Color of skin, light ochraceous buff. Also has fine netted appearance. Color of flesh, flesh ocher, intermixed with straw yellow. Somewhat variable. Peeling quality, good. Color of cooked potato, orange to cadmium (Pl. III, fig. 2). Consistency of freshly dug potatoes, firm to medium firm. Consistency after curing and storage, very soft. Tendency to darken, little. Canning quality, good.

Vineless "Yam." Vines fairly vigorous, compact, dense, bushy. Roots medium in size, fusiform in shape, smooth. Yields light. Color of skin, cinnamon buff. Color of flesh, ivory yellow suffused with pale pinkish cinnamon. Peeling quality, poor. Color of cooked potato, apricot yellow to empire yellow (Pl. III, fig. 3). Consistency of freshly dug potatoes, medium firm. Consistency after curing and storage, soft. Tendency to darken, pronounced. Canning quality, fair.

White "Yam." Vines medium in length and vigor. Roots medium in size, fusiform, regular. Yields, medium heavy. Color of skin, cream buff. Color of flesh, massicot yellow. Peeling quality, very poor. Color of cooked potato, empire yellow to apricot yellow (Pl. III, fig. 4). Consistency of freshly dug potatoes, firm to medium firm. Consistency after curing and storage, very soft. Tendency to darken, pronounced. Canning quality, fair.

- Yellow Jersey.** Vines small, slender, long, 6 to 12 feet. Roots small to medium in size, long or short fusiform to globular or ovoid in shape, smooth or veined. Yields, medium to heavy. Color of skin, cinnamon buff. Color of flesh, colonial buff interspersed with salmon color. Peeling quality, fair. Color of cooked potato, empire yellow to apricot yellow (Pl. III, fig. 5). Consistency after curing and storage, firm. Tendency to darken, little or none. Canning quality, good.
- Yellow Strasburg.** Vines large and vigorous, long, creeping, 6 to 15 feet. Roots medium to large in size, ovoid or globular in shape, fairly smooth and regular or quite irregular. Yields, very heavy, heaviest of varieties under study. Color of skin, cream buff. Color of flesh, uniformly massicot yellow, Cortex, straw yellow. Peeling quality, fair. Color of cooked potato, empire yellow to apricot yellow (Pl. III, fig. 6). Consistency of freshly dug potatoes, very firm. Consistency after curing and storage, firm. Tendency to darken, little. Canning quality, good.
- Yellow "Yam."** Vines low and slender, long creeping, 6 to 12 feet. Roots medium in size, fusiform in shape, low veins, regular. Yields, medium to heavy. Color of skin, cream buff. Color of flesh, nearly uniform ivory yellow with occasional flecks of flesh color in the cortex. Peeling quality, good. Color of cooked potato, apricot yellow to light orange yellow (Pl. III, fig. 7). Consistency of freshly dug potatoes, firm. Consistency after curing and storage, medium soft. Tendency to darken, little. Canning quality, fair.
- No. 10412.** Vines vigorous, long, spreading. Roots medium to very large, somewhat ribbed, fairly smooth. Yields, medium to heavy. Color of skin, dark vinaceous. Color of flesh, uniform straw yellow. Peeling quality, fair. Color of cooked potato, empire yellow to apricot yellow (Pl. III, fig. 8). Consistency of freshly dug potatoes, firm. Consistency after curing and storage, medium firm. Tendency to darken, very pronounced. Canning quality, fair.
- No. 10650.** Vines vigorous, long, spreading. Roots medium to very large, fusiform to globular in shape, ribbed, and irregular. Yields, medium heavy. Color of skin, dark vinaceous to slightly lighter shade, irregular. Color of flesh, uniform straw yellow. Peeling quality, good. Color of cooked potato, empire yellow to apricot yellow (Pl. III, fig. 9). Consistency of freshly dug potatoes, firm. Consistency after curing and storage, medium firm. Tendency to darken, pronounced. Canning quality, fair.
- No. 11284.** Vines vigorous, long, spreading. Roots medium to large in size, irregular, ribbed. Yields light. Color of skin, dark vinaceous. Color of flesh, fairly uniform straw yellow. Peeling quality, fair. Color of cooked potato, empire yellow (Pl. III, fig. 10). Consistency of freshly dug potatoes, firm. Consistency after curing and storage, medium firm. Tendency to darken, pronounced. Canning quality, fair.
- No. 11285.** Vines vigorous, spreading. Roots medium to very large, irregular, ribbed. Yields, medium heavy. Color of skin, cream color. Color of flesh, straw yellow. Peeling quality, fair. Color of cooked potato, empire yellow to apricot yellow (Pl. III, fig. 11). Consistency of freshly dug potatoes, firm to medium firm. Consistency after curing and storage, medium soft. Tendency to darken, pronounced. Canning quality, poor.
- No. 12686.** Vines medium vigorous, long, low, spreading. Roots medium to large, irregular, ribbed. Yields, medium heavy. Color of skin, dark vinaceous to slightly lighter shade, irregular. Color of flesh, uniform straw yellow. Peeling quality, fair. Color of cooked potato, empire yellow to

apricot yellow (Pl. III, fig. 12). Consistency of freshly dug potatoes, firm to medium firm. Consistency after curing and storage, soft. Tendency to darken, pronounced. Canning quality, fair.

No. 39833. Vines vigorous, stalky, somewhat bunchy. Roots medium to very large in size, elongated, irregular. Yields, medium heavy. Color of skin, light buff. Color of flesh, baryta yellow. Peeling quality, good. Color of cooked potato, empire yellow (Pl. III, fig. 13). Consistency of freshly dug potatoes, firm to medium firm. Consistency after curing and storage, soft. Tendency to darken, very pronounced. Canning quality, fair.

No. 49711. Vines vigorous, spreading. Roots medium to large, fusiform in shape, smooth. Yields, medium heavy. Peeling quality, fair. Color of skin, light buff. Color of flesh, baryta yellow. Color of cooked potato, empire yellow to apricot yellow (Pl. III, fig. 14). Consistency of freshly dug potatoes, firm to medium firm. Consistency after curing and storage, medium firm. Tendency to darken, pronounced. Canning quality, fair.

SUMMARY.

(1) In the comparative tests of the canning qualities of sweet-potato varieties and strains grown at the Arlington Experimental Farm the Gold Skin was awarded first place for two consecutive seasons by the committee judging the quality of the product. Of the other varieties the Yellow Jersey, Early Red Carolina, and Big-Stem Jersey represent the best of the dry firm types; the Dooley, Porto Rico, Nancy Hall, Mullihan, and Vineless Pumpkin "yam" the deep-colored moist group; and the Belmont, Miles, and Yellow Strasburg the lighter fleshed medium moist type.

(2) In determining the value of any variety for canning purposes there are many things to be considered, such as size, shape, ease of peeling, and yield per acre. Several varieties that are satisfactory on these points vary greatly in firmness, color, sweetness, and flavor. The final choice depends upon what is desired in the finished product. The Porto Rico, Dooley, and Vineless Pumpkin "Yam" are deep-colored sweet varieties, but they have a tendency to become very soft in storage. The Triumph, Miles, and Southern Queen are light colored, but become soft to medium soft in storage. The Big-Stem Jersey, Early Red Carolina, and Yellow Jersey are intermediate in color and yield the firmest product of any of the varieties. Almost every combination of qualities is found in some variety.

Certain changes take place after digging which alter greatly the firmness, flavor, and sweetness of the canned product. The varieties differ in the degree of change in each of these characters. This behavior greatly aids in choosing the type of product that the market demands. The home canner will find something desirable whatever may be his particular preference.

(3) In these tests material from each of the varieties has been canned as nearly whole as possible and also after passing through a food grinder in order to obtain a uniform product. The ground ma-

terial, commonly known as "pie stock," is more uniform in color and texture and is equally as attractive. It is suitable for making pies, puddings, etc., and the firmer varieties may even be sliced and used in other ways. The material canned as whole potatoes retains to a greater degree the original form and shape of the potatoes, which seems to be the only possible advantage to the housewife. For the canner, packing whole may have a slight advantage in that the method is simpler, but canning as pie stock utilizes the entire crop, large potatoes as well as small.

(4) The principal difficulty in canning sweet potatoes is due to the tendency of the cooked potato to darken on exposure to the air. When it is cooked in steam so as to exclude the air it assumes a clear bright color. On cooling in the air a darkening occurs, which is more marked in some varieties than in others. This discoloration disappears on reheating in steam but reappears on exposure to air. Metallic iron and iron salts accelerate and intensify this discoloration, and when large quantities are present and the material is exposed to the air for a considerable time it becomes black and the original brightness is not regained by reheating.

In canning sweet potatoes if the air or oxygen is not excluded the mass darkens, the metal of the container is acted upon, and the material in time becomes black. If the air or oxygen is excluded the material remains bright. Filling the can at a temperature of 80° C. or above and sealing at once effect this more easily and completely than filling the can cold and then exhausting in the usual way. If the can is opened immediately after processing there is a slight tendency to darken on exposure to the air, but this tendency slowly disappears in storage. In these tests material kept in cans for one year showed no tendency to darken on exposure to the air.

(5) The physical character of sweet potatoes is such that the penetration of heat into the mass is very slow. This so affects the length of the processing necessary to sterilize the product that the material should be filled into the can hot, sealed at a temperature not below 70° C., and processed immediately. If it becomes necessary to delay the work, the cans should be kept at the sealing temperature until they can be processed. The rate at which heat penetrates the can varies but little among the different varieties, and for practical purposes the variation is negligible.

(6) The sweet potato has a high sugar content; hence, its flavor and quality are easily injured by long cooking at high temperatures. The time and temperature of processing, therefore, must be carefully adjusted.

(7) The plasticity of the sweet potato after cooking is due to the nature of its carbohydrate content. The potatoes which remain firm after cooking contain a high percentage of starch, while those which

become soft have a low percentage of starch but a comparatively high percentage of dextrin. During canning, storage, and cooking the starch is transformed into sugar, dextrin, and probably all the intermediate products, the proportions in which they are formed varying with the method of handling and with different varieties. Changes in plasticity are due to these transformations, which affect the ratio of starch to moisture.

(8) The essential points in the canning of sweet potatoes are:

(a) Steaming for a sufficient length of time to make peeling rapid and easy and to cook the potato.

(b) Handling so as to expose the cooked material to the air for the minimum time possible.

(c) Packing the cans as full as convenient in order to eliminate oxygen and prevent darkening.

(d) Filling the can with material as hot as possible, not below 70° C., in order to exclude oxygen and shorten the processing period required.

(e) Avoiding bringing the material into contact with iron or iron compounds.

(f) Processing the material the minimum length of time necessary to insure its safe preservation.

LITERATURE CITED.

- (1) ATWATER, W. O., and BRYANT, A. P.
1906. The chemical composition of American food materials. U. S. Dept. Agr., Office Exp. Sta. Bul. 28, rev., 87 p., 4 fig.
- (2) BIGELOW, W. D., and CATHCART, P. H.
1921. Relation of processing to the acidity of canned foods. Bul. 17-L Research Lab., Nat. Cannery Assoc., 46 p., 16 fig.
- (3) BROWNE, C. A.
1912. Handbook of Sugar Analysis . . . xi, 787, 101, lxxi p., 200 fig. Bibliographical footnotes.
- (4) CAMPBELL, C. H.
1920. To prevent discoloration of sweet potatoes in cans. *In* West. Canner and Packer, v. 12, no. 2, p. 11.
- (5) CARVER, G. W.
1918. How to make sweet potato flour, starch, sugar, bread and mock cocoanut. Ala. Tuskegee Agr. Exp. Sta. Bul. 37, 6 p.
- (6) GORE, H. C.
1921. Preparation of sweet potato sirup. *In* Chem. Age, v. 29, no. 4, p. 151-153, 1 fig.
- (7) HARRINGTON, H. H.
1895. Water and sugar in sweet potatoes, as influenced by keeping. *In* Tex. Agr. Exp. Sta. Bul. 36, p. 628-629.
- (8) HASSELBRING, HEINRICH, and HAWKINS, LON A.
1915. Physiological changes in sweet potatoes during storage. *In* Jour. Agr. Research, v. 3, no. 4, p. 331-342. Literature cited, p. 341-342.
- (9) 1915. Respiration experiments with sweet potatoes. *In* Jour. Agr. Research, v. 5, no. 12, p. 509-517. Literature cited, p. 517.
- (10) 1915. Carbohydrate transformations in sweet potatoes. *In* Jour. Agr. Research, v. 5, no. 13, p. 543-560.
- (11) KEITT, T. E.
1909. Sweet potato work in 1908. S. C. Agr. Exp. Sta. Bul. 146, 21 p.
- (12) 1911. The formation of sugars and starch in the sweet potato. S. C. Agr. Exp. Sta. Bul. 156, 14 p.
- (13) 1912. Sweet potato investigation. S. C. Agr. Exp. Sta. Bul. 165, 43 p.
- (14) KOHMAN, EDWARD F.
1921. Discoloration in canned sweet potatoes. *In* Jour. Indust. and Engin. Chem., v. 13, no. 7, p. 634-635.
- (15) McDONNELL, C. C.
1908. The manufacture of starch from sweet potatoes. S. C. Agr. Exp. Sta. Bul. 136, 50 p., 5 fig., 4 pl. (in text).
- (16) MANGELS, C. E., and PRESCOTT, S. C.
1921. Manufacture of sweet potato flour by the "flake" process. *In* Chem. Age, v. 29, no. 4, p. 132-135, 1 fig.

(17) MIYAKE, KIUCHI.

1915. On the nature of the sugars found in the tubers of sweet potatoes.

In Jour. Biol. Chem., v. 21, no. 2, p. 503-506.

(18) SHIVER, F. S.

1901. Sweet potato. *S. C. Agr. Exp. Sta. Bul.* 63, 37 p.

(19) THOMPSON, H. C., and BEATTIE, JAMES H.

1922. Group classification and varietal descriptions of American varieties of sweet potatoes. *U. S. Dept. Agr. Bul.* 1021, 30 p., 8 pl. (partly col.) Literature cited, p. 26-30.

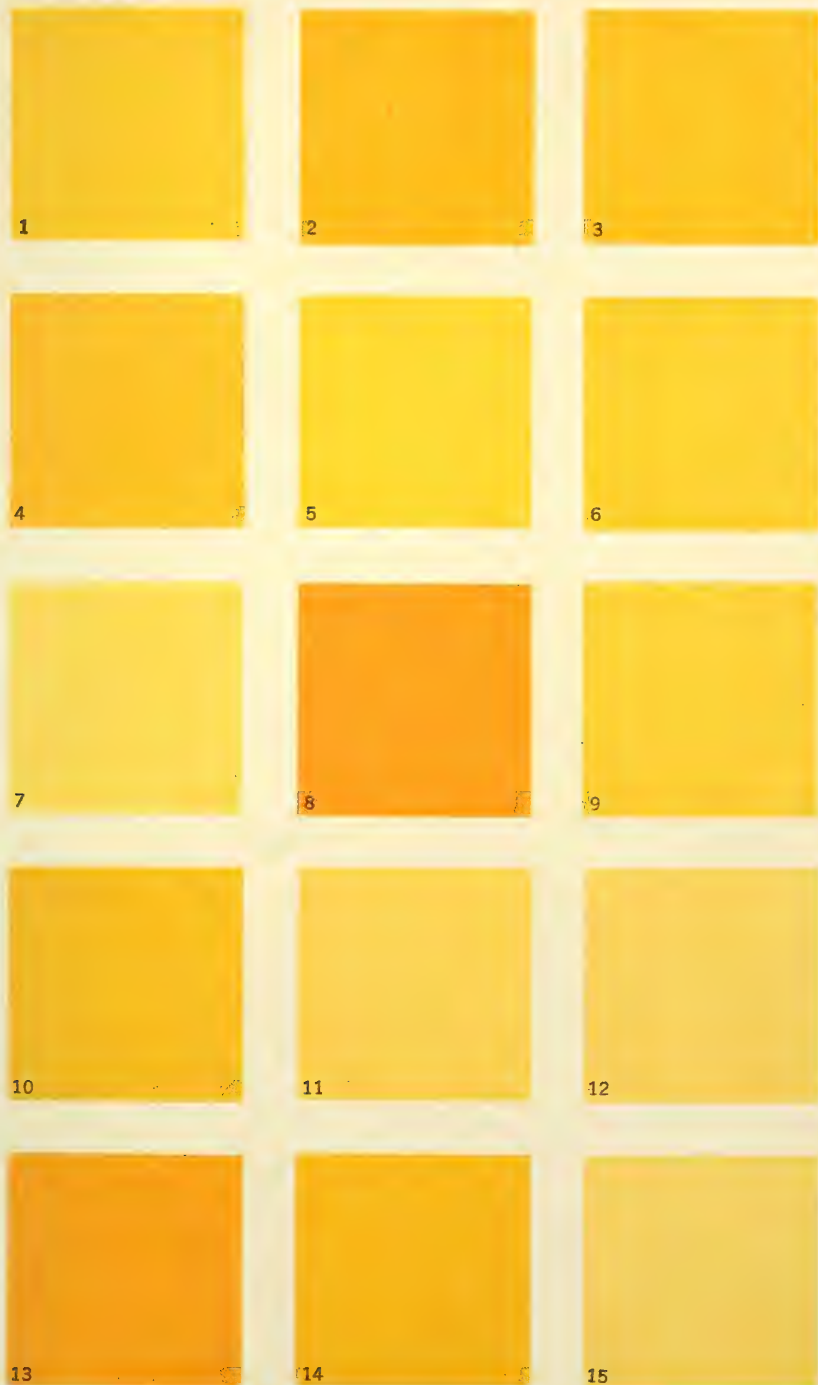
(20) WEINZIRL, JOHN.

1919. The bacteriology of canned foods. *In Jour. Med. Research*, v. 39, no. 3 (172), p. 349-413. Bibliography, p. 411-413.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.

AT
10 CENTS PER COPY

▽



R. C. STEADMAN

A. Hoen & Co. Baltimore

**SHADES OF COLOR OF DIFFERENT VARIETIES OF SWEET POTATOES WHEN
CANNED IN THE FORM OF PIE STOCK. I.**

Explanation of figures: 1, Ballinger's Pride; 2, Belmont; 3, Big-Stem Jersey; 4, Catawba White; 5, Catawba Yellow; 6, Creola; 7, Dahomey; 8, Dooley; 9, Early Carolina; 10, Early Red Carolina; 11, Florida; 12, General Grant; 13, Golden Beauty; 14, Gold Skin; 15, Gros Grandia.

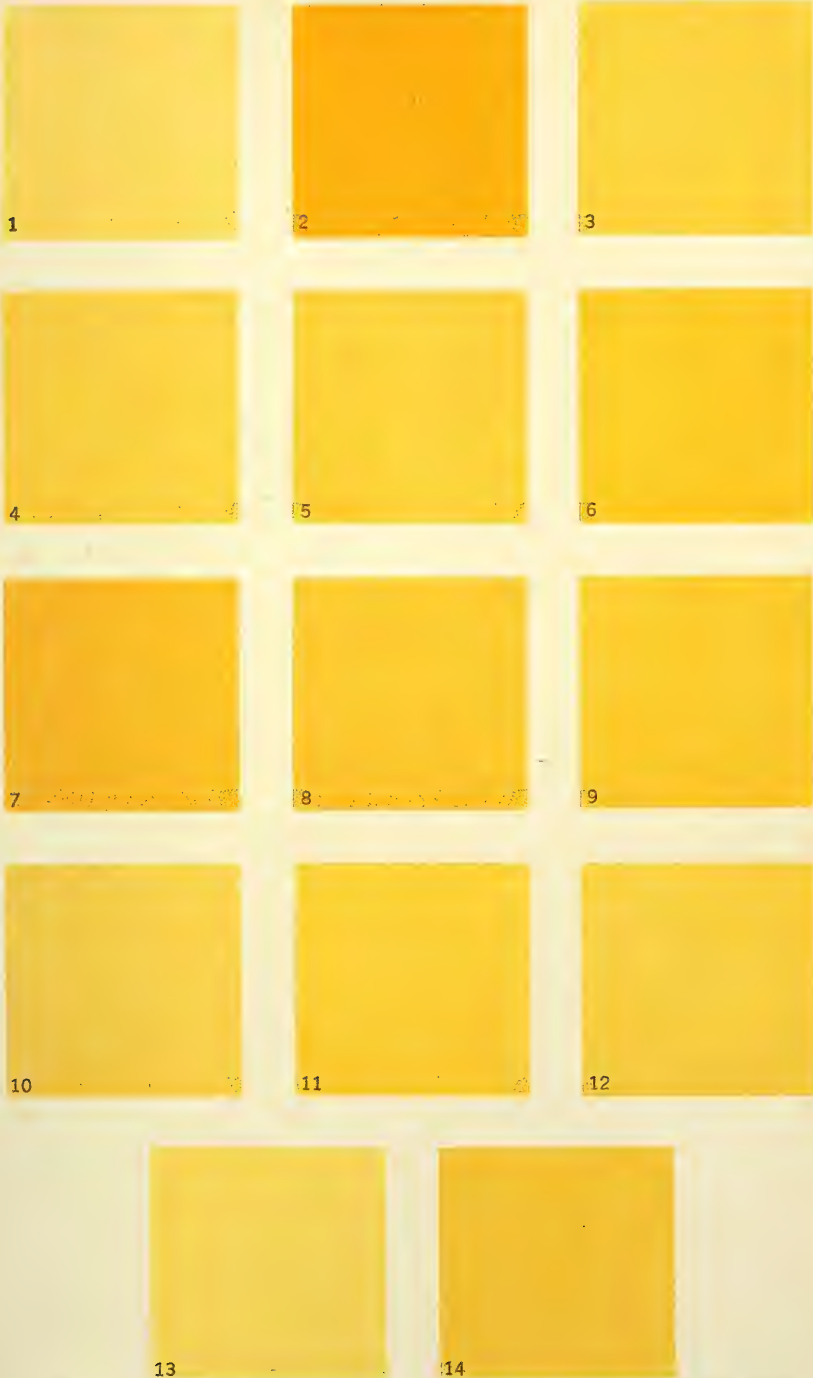


R. C. STEADMAN

A. H. H. & Co. Baltimore

SHADES OF COLOR OF DIFFERENT VARIETIES OF SWEET POTATOES WHEN CANNED IN THE FORM OF PIE STOCK. II.

Explanation of figures: 1, Haiti; 2, Improved Big Stem; 3, Japanese "Yam"; 4, Key West; 5, Miles; 6, Mullihan; 7, Nancy Hall; 8, Pierson; 9, Porto Rico; 10, Pumpkin "Yam"; 11, Purple "Yam"; 12, Red Bermuda; 13, Red Brazil; 14, Red Jersey; 15, Southern Queen.



R. C. STEADMAN

A. Haen & Co Baltimore

SHADES OF COLOR OF DIFFERENT VARIETIES OF SWEET POTATOES WHEN
CANNED IN THE FORM OF PIE STOCK. III.

Explanation of figures: 1, Triumph; 2, Vineless Pumpkin "Yam"; 3, Vineless "Yam"; 4, White "Yam"; 5, Yellow Jersey; 6, Yellow Strasburg; 7, Yellow "Yam"; 8, No. 10412; 9, No. 10650; 10, No. 11284; 11, No. 11285; 12, No. 12686; 13, No. 39833; 14, No. 49711.





BULLETIN No. 1042



Contribution from the Bureau of Animal Industry
JOHN R. MOHLER, Chief

Washington, D. C.

February 4, 1922

EFFECT OF WINTER RATIONS ON PASTURE GAINS OF CALVES.¹

By E. W. SHEETS and R. H. TUCKWILLER, *Animal Husbandry Division*.²

I. WINTER RATIONS AND THEIR INFLUENCE ON PASTURE GAINS OF CALVES.

II. THE COST OF RATIONS FOR WINTERING CALVES.

CONTENTS.

	Page.		Page.
Outline of the experimental work.....	1	I. Winter rations and their influence	
The region and its problems.....	2	on pasture gains of calves—	
Objects and plan of the work.....	3	Continued.	
Kind of calves used.....	3	Gains during summer.....	8
Feeds used.....	3	Gains for winter and summer.....	8
Character of pasture.....	5	Diagrams of gains and losses.....	9
Method of feeding and handling		Summary of feeding.....	11
the calves.....	5	II. Cost of rations for wintering	
I. Winter rations and their influence		calves.....	11
on pasture gains of calves.....	6	Cost per pound of gain.....	13
Quantity of feed consumed.....	6	Summary of costs.....	15
Gains during winter.....	7		

OUTLINE OF THE EXPERIMENTAL WORK.

The work reported in this bulletin is part of a series of experiments on beef-production problems in the Appalachian Mountain region that have been in progress since December 22, 1914, in cooperation between the Bureau of Animal Industry of the United States Department of Agriculture and the West Virginia Agricultural Experiment Station, on the farm of David Tuckwiller, in Greenbrier County, W. Va. This farm is located in the southeastern part of the State in the blue-grass area. The results of this experiment apply not only to West Virginia but also to the adjacent States

¹ A report of cooperative work by the Bureau of Animal Industry, United States Department of Agriculture, and the West Virginia Agricultural Experiment Station.

² The authors acknowledge the services of W. F. Ward and F. W. Farley, formerly of the Animal Husbandry Division, who assisted in planning and carrying on the work.

having similar conditions, as shown in figure 1. Some of the methods and results may be utilized to advantage by cattle feeders in other parts of the country.

THE REGION AND ITS PROBLEMS.

The topography in most parts of the region, except in the vicinity of streams, is gently rolling or even mountainous in the higher elevations. The region is generally cleared of forest trees, although vast areas of cut-over or stump land are found. The farms vary in size from less than 100 acres to more than 1,000 acres. The land is especially adapted for grazing purposes. In most sections there is

tillable land for the production of abundant crops for winter feed or other purposes.

It is in this general area that a large percentage of the grass-finished cattle which go annually to eastern markets are produced. The fact that most of the steers raised in this area are finished for market from grass alone attests the value of the pastures, which consist largely of blue grass. The use of grain for finishing cattle is not general, although there are many sections where the practice is followed, particularly in the valleys of some of the larger streams. By far the larger number of farmers who handle beef cattle grow either stockers and feeders or finish cattle for market



FIG. 1.—Map showing region to which this work applies. The black dot indicates the location of the farm on which the experiment was conducted. The shaded portion represents the area to which the results are applicable, and the dotted portion shows an additional area to which the results apply in part.

from grass alone. It therefore becomes one of the principal beef-production problems in this general area to determine the best and most economical method of wintering the cattle and the one that will enable them to make the best possible use of the pasture the following summer, the time when the cheapest gains are made. A common practice in this area has been to winter steers on dry feed, such as hay, corn stover, and wheat straw, and on corn silage to a less extent, in a way that causes them to lose materially in weight. They are then pastured the following summer and sold from grass either as stockers or feeders or as finished steers for the market. There are some who hold the idea that it is profitable to permit this loss of weight, which with older steers often amounts to from 25 to 100 pounds. Others believe that cattle wintered on silage, or on a

ration of which silage is a part, will not do well on grass the following summer.

OBJECTS AND PLAN OF THE WORK.

The experiments as a whole had these general problems in view:

1. To ascertain the effect of different wintering rations upon subsequent pasture gains.
2. To determine the most satisfactory and economical method of wintering.
3. To determine the best method and the cost of raising beef cattle in West Virginia.

Two distinct phases of the problems as above outlined presented themselves for solution: First, the keeping of grade beef cows to raise calves; second, the wintering of calves, yearlings, and 2-year-olds that are to be pastured the following summer and sold as stockers, feeders, or fat cattle. This bulletin takes up the work with calves. The results of the work with yearlings and cows are published in United States Department of Agriculture Bulletins 870 and 1024, respectively.

The work was carried on for a period of three years, in order to have an average of feeds, cattle, seasons, and other conditions tending to produce variation. The general plan of the experiments, including the rations used for the different lots of calves, is given in Table 1.

TABLE 1.—*Plan of the three years' work.*

Lot No.	Season.	Calves in lot.	Winter feed.	Summer feed.
1.....	1916-17	10	Corn silage, rye hay, and cottonseed meal.	Pasture.
	1917-18	10	do.	Do.
	1918-19	10	do.	Do.
2.....	1916-17	10	Corn silage and clover hay.	Do.
	1917-18	10	do.	Do.
	1918-19	10	do.	Do.
3.....	1916-17	10	Mixed hay and grain mixture ¹ .	Do.
	1917-18	10	do.	Do.
	1918-19	10	do.	Do.

¹ Grain mixture, parts by weight: 3 parts corn, 1 part bran, 1 part linseed meal.

KIND OF CALVES USED.

The calves used were grade Shorthorn, Hereford, and Aberdeen Angus. They were raised in southern West Virginia and were a good, uniform lot in age, weight, quality, and condition. They ranged in weight from 300 to 500 pounds, averaging 385 pounds at the beginning of the winter period, and were 1 year old the following spring.

FEEDS USED.

Samples of each of the feeds used were taken at different times during the winter periods and sent to the department of chemistry, West Virginia Agricultural Experiment Station, Morgantown.

W. Va., to be analyzed. The averages of these analyses are given in Table 2 in heavy type. The average analyses for several thousand other samples are also shown for comparison.



FIG. 2.—The type of calves and pasture used in the experimental work.

TABLE 2.—Composition of feeds used.

Feed.	Moisture.	Ash.	Protein.	Carbo- hydrates, including fiber.	Fat.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Corn silage.....	75	1.1	1.9	21.5	0.5
	70.9	1.4	2.4	24.4	.9
Mixed hay.....	8.3	3.7	6.6	79.5	1.9
Rye hay.....	8.5	4.7	5.8	79.8	1.2
	6.4	4.7	5.9	81	2
Clover hay.....	8.6	4.4	8.7	76.6	1.7
	12.9	6.9	13.6	63.2	3.4
Shelled corn.....	12.6	1.3	9	73	4.1
	12.9	1.3	9.3	72.2	4.3
Wheat bran.....	10.2	5.3	15	65.9	3.6
	9.6	5.9	16.2	64.1	4.2
Linseed meal.....	8.4	6.3	30	48.1	7.2
	8.9	5.4	34.5	44.4	6.8
Cottonseed meal.....	7.8	6	37.6	40.3	8.3
	7.3	5.8	36.8	43.5	6.6

From the analyses it is evident that the feeds used were somewhat below the average in quality. The cottonseed meal was slightly better than the average of that which is graded as good by the Association of Feed Control Officials of the United States. The silage was made from a mixture of dent and silage corn.

A three-year rotation of crops, consisting of corn, wheat, and hay, is practiced quite generally in the section under discussion. Timothy is sown with the wheat in the fall and red clover is sown on the same

field in the spring. This provides in the year following the wheat crop a mixed hay of approximately one-half timothy and one-half clover. The mixed hay used in this work was obtained in this manner.

In making rye hay the seed is sown in the fall, as it would be for raising grain, except that more seed per acre is used. In the spring, just before the rye blooms, it is cut and cured.



FIG. 3.—Lot 1, calves fed corn silage, rye hay, and cottonseed meal. Photographed at the end of the winter period, April 25, 1919.

CHARACTER OF PASTURE.

Each year the calves were turned on to a rather rough, hilly pasture of about 200 acres, one-half of which is woodland. A small stream, which flows through the pasture, provides an abundance of fresh water at all times throughout the summer.

The soil is of limestone formation. A fairly good growth of blue grass with white clover is found on all parts of the pasture not in timber. Under normal climatic conditions there is rainfall enough to keep the grass growing throughout the season. However, the latter part of the summer of 1917 was so dry that the calves made only small gains, as shown in figures 6, 7, and 8.

METHOD OF FEEDING AND HANDLING THE CALVES.

In the fall before starting the calves on winter feed they were divided into lots of 10 each. In making this division care was taken to have the lots as nearly uniform as possible in quality, breeding, size, and condition. The different lots were given the same amount of space in open sheds with small outside lots about 30 by 60 feet

in size. Water was supplied in these lots at all times and salt was constantly available. The calves were fed twice a day.

The feed, both concentrates and roughages, was weighed at each feeding, and accurate records of it kept. The calves were weighed at the beginning and at the end of the feeding period, the weights being taken three days in succession and the average taken as their initial and final weights. They were also weighed once every 28 days, in the morning after feeding. Neck straps with numbers on them were used so that the identification of each individual could be accurately kept.

In the spring of each year, as soon as the grass was good enough, which was usually about April 22, the calves from all the lots were turned into the same pasture with no additional feed. Weights were taken once every 28 days, just as during the winter. Thus the effects



FIG. 4.—Lot 2, calves fed corn silage and clover hay. Photographed at the end of the winter period, April 25, 1919.

of the different rations upon the summer grazing of the different lots could be studied.

I. WINTER RATIONS AND THEIR INFLUENCE ON PASTURE GAINS OF CALVES.

QUANTITY OF FEED CONSUMED.

In considering the quantity of feed consumed it should be kept in mind that the calves were not getting fattening rations, but only enough to keep them in thrifty growing condition. Table 3 shows the total amount of different feeds eaten in the various lots and the average daily ration per calf in each lot during each of the three winters.

TABLE 3.—Average total and daily rations per calf during three winters.

Ration.	Total feed per calf.				Daily feed per calf.			
	1916-17 (133 days).	1917-18 (134 days).	1918-19 (135 days).	Average (134 days).	1916-17 (133 days).	1917-18 (134 days).	1918-19 (135 days).	Average (134 days).
Lot 1:	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
Corn silage.....	1,596	1,608	1,730	1,645	12.0	12.0	12.8	12.3
Rye hay.....	560	536	478	525	4.2	4.0	3.5	3.9
Cottonseed meal.....	66	67	101	78	.5	.5	.7	.6
Lot 2:								
Corn silage.....	1,596	1,608	1,730	1,645	12.0	12.0	12.8	12.3
Clover hay.....	661	736	561	653	5.0	5.0	4.2	4.9
Lot 3:								
Mixed hay.....	1,064	1,284	1,346	1,231	8.0	9.6	10.0	9.2
Grain mixture.....	383	402	270	352	2.9	3.0	2.0	2.6

The composition and nutritive ratio of the rations fed are given in Table 4.

TABLE 4.—Quantities of dry matter, digestible nutrients, and nutritive ratios of the daily rations.

Lot No.	Daily ration per calf.	Dry matter.	Digestible nutrients.			Feed per 1,000 pounds live weight. ²
			Protein.	Carbohydrate equivalent. ¹	Nutritive ratio.	
		<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>		<i>Pounds.</i>
1.	Corn silage (12.3 pounds).....	3.07	0.17	2.32	.....	32.0
	Rye hay (3.9 pounds).....	3.57	.12	1.77	.....	10.2
	Cottonseed meal (0.6 pound).....	.55	.19	.25	.....	1.6
	Total.....	7.19	.48	4.34	1 : 9	.....
2.	Corn silage (12.3 pounds).....	3.07	.17	2.32	.....	31.9
	Clover hay (4.9 pounds).....	4.48	.41	2.12	.....	12.7
	Total.....	7.55	.58	4.44	1 : 7.7	.....
3.	Mixed hay (9.2 pounds).....	8.44	.53	4.04	.....	24.0
	Grain mixture (2.6 pounds).....	2.31	.33	1.66	.....	6.8
	Total.....	10.75	.86	5.70	1 : 6.6	.....

¹ The carbohydrate equivalent is the sum of the digestible carbohydrates plus 2.25 times the digestible fat.

² Rations based on the initial weights of the calves.

From Table 4 it is seen that the ration given Lot 3 provided considerably more dry matter than the rations given Lots 1 and 2, the two latter being nearly the same. Lot 3 also received more total digestible nutrients than the other two lots.

GAINS DURING WINTER.

The gains and losses in weight during each of the three winters are shown in Table 5.

TABLE 5.—*Total and daily gains during three winters.*

Lot No.	Ration.	Season.	Number of calves.	Days on feed.	Average initial weight per calf.	Average weight per calf at end of winter.	Total gain per calf.	Daily gain per calf.
				<i>Days.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1	Corn silage, rye hay, and cottonseed meal.....	1916-17	10	133	426	482	56	0.42
		1917-18	10	134	344	386	42	.31
		1918-19	10	135	383	449	66	.49
	Average.....		10	134	384	439	55	.41
2	Corn silage and clover hay ..	1916-17	10	133	429	470	41	.31
		1917-18	10	134	342	386	44	.33
		1918-19	10	135	383	438	55	.41
	Average.....		10	134	385	431	46	.34
3	Mixed hay and grain.....	1916-17	10	133	429	502	73	.55
		1917-18	10	134	340	442	102	.76
		1918-19	10	135	384	502	118	.87
	Average.....		10	134	384	482	98	.73

Table 5 shows that the gains for each of the three winters are quite uniform in the case of each ration.

GAINS DURING SUMMER.

Table 6 shows the weights at the beginning of the grazing period, the weights at the end of the grazing period, and the total and average gains per calf for the summer period.

TABLE 6.—*Total and daily gains during three summers on pasture.*

Lot No.	Previous winter ration.	Season.	Number of calves.	Days on pasture.	Average weight per calf at beginning of grazing period.	Average final weight per calf.	Total gain per calf.	Daily gain per calf.
				<i>Days.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1	Corn silage, rye hay, and cottonseed meal.....	1916-17	10	168	482	667	185	1.10
		1917-18	10	168	386	590	204	1.21
		1918-19	10	168	449	640	191	1.14
	Average.....		10	168	439	632	193	1.15
2	Corn silage and clover hay..	1916-17	10	168	470	687	217	1.29
		1917-18	10	168	386	580	194	1.16
		1918-19	10	168	438	602	164	.98
	Average.....		10	168	431	623	192	1.14
3	Mixed hay and grain.....	1916-17	10	168	502	695	193	1.15
		1917-18	10	168	442	623	181	1.08
		1918-19	10	168	502	674	172	1.02
	Average.....		10	168	482	664	182	1.08

GAINS FOR WINTER AND SUMMER.

The gains in weight for both winter and summer are summarized in Table 7, with averages for the three years.

TABLE 7.—*Summary of gains in weight per calf, winter and summer.*

Lot No.	Ration.	Season.	Gain per calf in winter.	Gain per calf in summer.	Total gain per calf.	Daily gain per calf.
			<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
1	Corn silage, rye hay, and cottonseed meal	1916-17	56	185	241	0.80
		1917-18	42	204	246	.81
		1918-19	66	191	257	.85
	Average.....		55	193	248	.82
2	Corn silage and clover hay	1916-17	41	217	258	.85
		1917-18	44	194	238	.79
		1918-19	55	164	219	.73
	Average.....		46	192	238	.79
3	Mixed hay and grain	1916-17	73	193	266	.88
		1917-18	102	181	283	.94
		1918-19	118	172	290	.96
	Average.....		98	182	280	.93

DIAGRAMS OF GAINS AND LOSSES.

The four charts, figures 6, 7, 8, and 9, show the gains and losses of the calves by 28-day periods. The first three show the effects of the three rations under comparison for the three years they were



FIG. 5.—Lot 3, calves fed mixed hay and a grain mixture. Photographed at the end of the winter period, April 25, 1919.

used, one chart being used for each ration. The fourth chart shows the average gains for three years for each of the three rations.

Horizontal distance on the chart indicates the number of days that the calves were fed during the three winters and pastured during the three summers. The date on which each monthly period began is given also. The average length of the total period for the

three years was 302 days, of which 134 days were in the winter, or feeding period, and the remaining 168 in the summer, or grass period. The heavy black vertical line near the center of the chart marks the dividing line between the winter and summer periods.

Vertical distance on the chart represents changes in live weights of the calves. The weights corresponding to each of the horizontal lines are given along the left side of the chart.

Figure 6, for Lot 1, shows that the calves gained in weight very uniformly for the three years. They lost in weight only during the

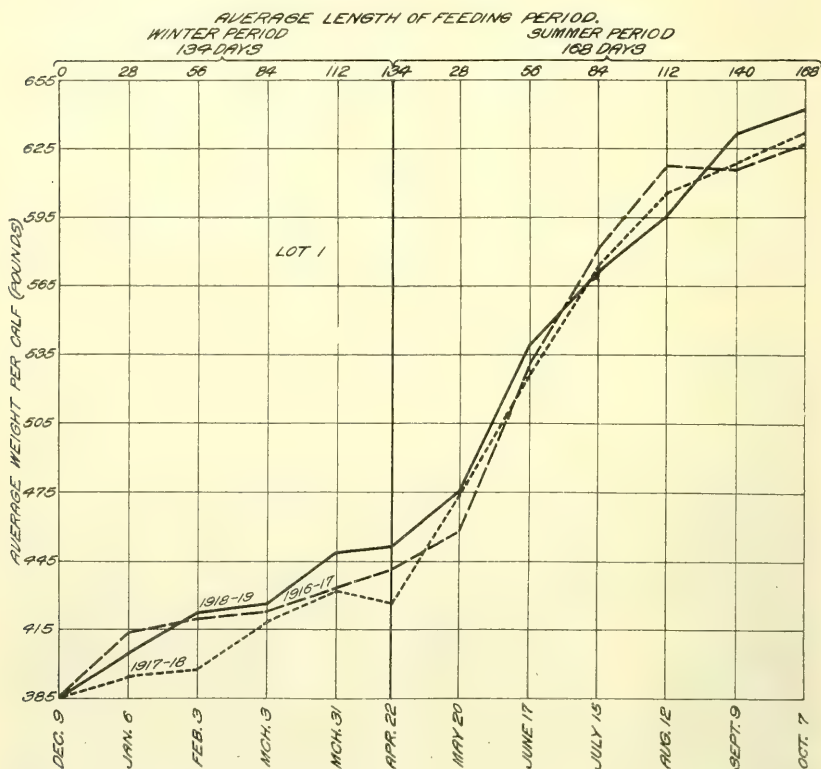


FIG. 6.—Annual results of winter and summer (grass) feeding for Lot 1. These calves were fed the following ration during the winter: Corn silage, 12.3 pounds; rye hay, 3.9 pounds; cottonseed meal, 0.6 pound.

last 22 days of the winter period of 1917-18 and the dry month of August, 1917.

Figure 7, for Lot 2, shows that the calves gained in weight uniformly for the three years, except that the summer gains for 1916-17 were considerably greater than for the two subsequent years. They also lost in weight during the last part of the winter period of 1916-17 and during the last 28 days on grass in 1918-19.

Figure 8, for Lot 3, shows that the calves gained in weight uniformly for the three years, except the periods just before and

just after they were turned to pasture. They also lost weight slightly in August, 1917. With these exceptions the calves each year gained uniformly during the first 28 days, but not nearly so much as they gained during the second 28 days on pasture. While the calves in Lot 3 gained much more than those of Lots 1 and 2 during the winter periods, they did not make so much gain as Lots 1 and 2 on pasture. Those which gained most or lost least during the winter made the least gains on grass.

SUMMARY OF FEEDING.

1. The following quantities of feed per day per calf averaging 385 pounds in weight at the beginning of the winter feeding period produced the corresponding gains in live weight for 134 days.

Lot No.	Average daily ration.	Pounds.	Total winter gain.
			<i>Pounds.</i>
1	Corn silage.....	12.3	55
	Rye hay.....	3.9	
	Cottonseed meal.....	.6	
2	Corn silage.....	12.3	46
	Clover hay.....	4.9	
	Mixed hay.....	9.2	
3	Grain mixture.....	2.6	98

2. The calves which made the greatest winter gain (Lot 3) also made the greatest total gain for the year, although they did not gain so much during the summer period as calves which put on less gain during the winter. Similar results, which are published in Department of Agriculture Bulletin No. 870, were obtained in handling yearling steers.

3. In wintering calves 4.9 pounds of clover hay (Lot 2) are practically equal to 3.9 pounds of rye hay and 0.6 pound of cottonseed meal (Lot 1) as a supplement to corn silage.

II. COST OF RATIONS FOR WINTERING CALVES.

Whether to purchase calves in the fall and carry them through the winter largely on roughage or to purchase them in the spring after some one else has wintered them is a question which the thoughtful cattle grazier tries to answer. No matter what the answer may be on any particular farm or in any particular section of the country, the fact remains that cattle are generally higher in price and are worth more in the spring just before the grass season opens than they were at the close of the pasture period the preceding fall. This increase in value is due to the cost of wintering and the demand for cattle to make use of grass in the spring. In the following discussion the various winter rations are compared to determine which is the

cheapest per day, and especially which produces a pound of gain most cheaply. For this purpose it is necessary to fix the prices for feeds on the farm. It is felt, however, that this is the most questionable and unsatisfactory part of such experimental work, especially for the last few years, during which unusual fluctuations have occurred in feed prices. On account of these fluctuations and

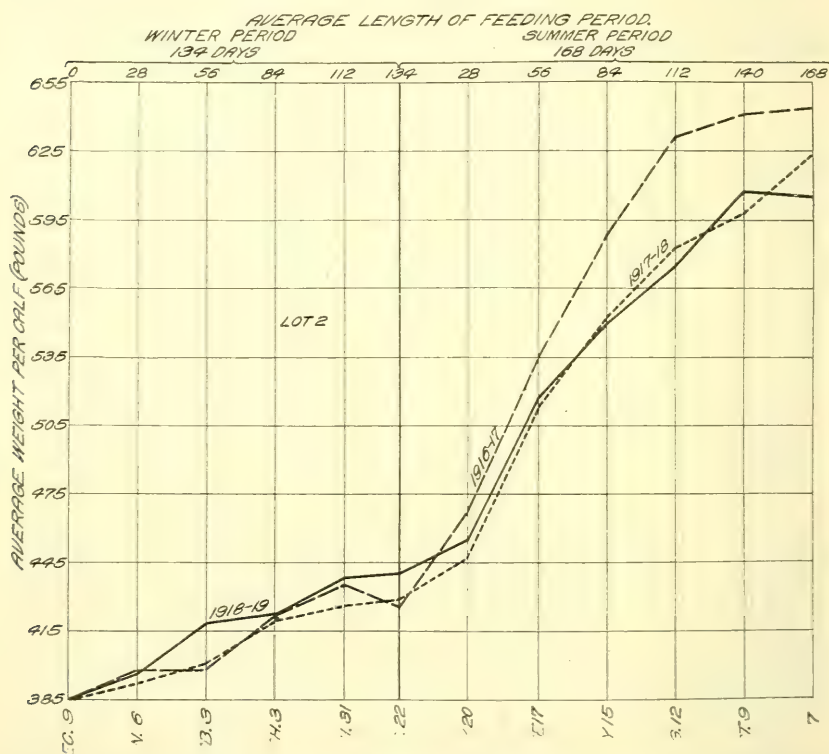


FIG. 7.—Annual results of winter and summer (grass) feeding for Lot 2. These calves were fed the following ration during the winter period: Corn silage, 12.3 pounds; clover hay, 4.9 pounds.

also for simplicity in making the various calculations an average of the feed prices for the three years is used, as follows:

Corn silage	per ton	\$6.00
Rye hay	do	18.00
Cottonseed meal	do	50.00
Clover hay	do	17.00
Mixed hay	do	18.00
Corn	per bushel	0.96
Wheat bran	per ton	40.00
Oil meal	do	56.00
Mixed grain	do	39.76
Pasture	per day	0.03

The foregoing figures are based on the average farm prices from 1910 to 1919 as given in the Yearbook of the United States Department of Agriculture for the States of West Virginia, Virginia, Maryland, Pennsylvania, Ohio, Kentucky, Tennessee, and North Carolina.

When one wishes to determine which ration should be used in a particular feeding operation, it is suggested that he apply local prices to

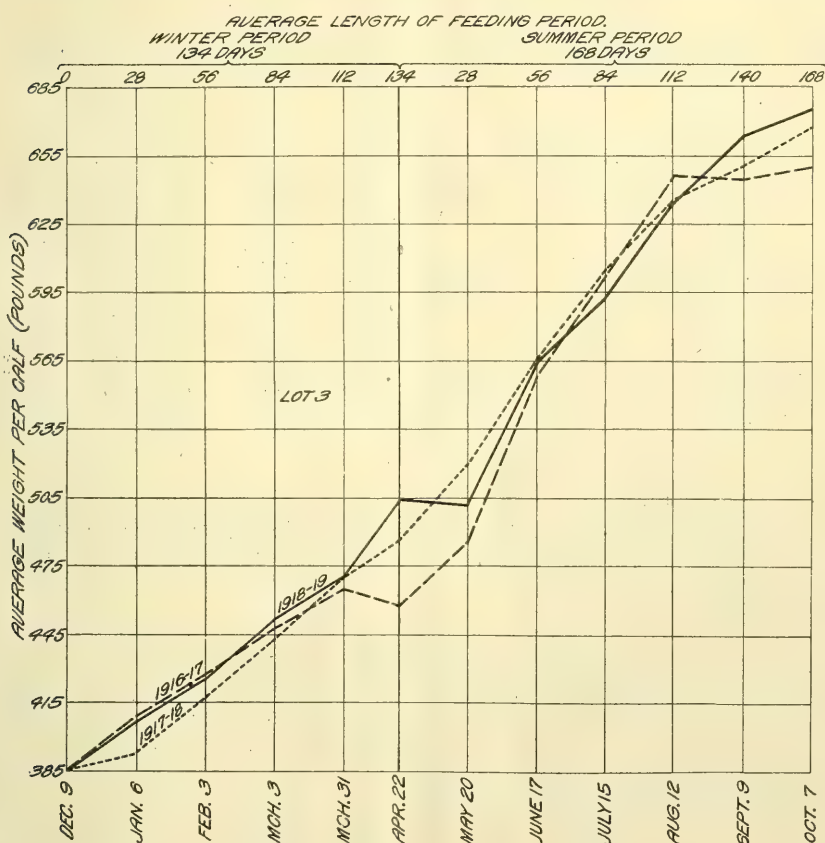


FIG. 8.—Annual results of winter and summer (grass) feeding for Lot 3. These calves were fed the following ration during the winter periods: Mixed hay, 9.2 pounds; grain mixture, 2.6 pounds.

the average amounts of the feeds consumed per calf, as given in Table 4.

COST PER POUND OF GAIN.

From Table 8 it will be noted that the winter cost constitutes approximately two-thirds of the total cost for the year. Most of the gain, however, is made during the summer or pasture season. Hence, the cost of wintering becomes the chief factor governing the cost of a pound of gain.

The cost of producing a pound of gain is one of the main factors in determining whether a calf is being produced at a profit or loss. It is considered that the cost of labor and other expenses are balanced by the manure produced.

TABLE 8.—*Costs of feeding.*

Lot No.	Ration.	Season.	Total gain winter and summer per calf.	Cost of feed per calf.			Cost per pound of yearly gain.
				Winter.	Summer.	Total.	
			<i>Pounds.</i>				<i>Cents.</i>
1	Corn silage, rye hay, and cottonseed meal.....	1916-17	238	\$11.49	\$5.60	\$17.09	0.072
		1917-18	246	11.32	5.60	16.92	.069
		1918-19	256	12.02	5.60	17.62	.069
	Average.....		247	11.61	5.60	17.21	.070
2	Corn silage and clover hay.....	1916-17	258	10.41	5.60	16.01	.062
		1917-18	238	10.08	5.60	15.68	.066
		1918-19	219	9.96	5.60	15.56	.071
	Average.....		238	10.15	5.60	15.75	.066
3	Mixed hay and grain mixture.....	1916-17	266	17.19	5.60	22.79	.086
		1917-18	283	19.55	5.60	25.15	.089
		1918-19	290	17.48	5.60	23.08	.080
	Average.....		280	18.07	5.60	23.67	.085

While the calves of Lot 2, which were fed corn silage and clover hay during the winter, made the least gains during the year, the cost of a pound of gain was lowest for this lot, the average for three years being 6.6 cents.

Lot 1, fed corn silage, rye hay, and cottonseed meal, put on gains for the year at an average cost of 7 cents a pound.

Lot 3, fed mixed hay and mixed grain, made greater annual gains but at much greater cost than the calves of the other two lots. It cost 8.4 cents to put on a pound of gain when the wintering ration consisted of mixed hay and grain.

TABLE 9.—*Summary of costs and gains.*

Item.	Lot 1.	Lot 2.	Lot 3.
Average cost of wintering.....	\$11.61	\$10.15	\$18.07
Average length of winter periods..... days..	134	134	134
Average gain per calf, winter..... pounds..	54	47	98
Cost of feeds per day, winter.....	\$0.087	\$0.076	\$0.135
Average cost of summer feed.....	\$5.60	\$5.60	\$5.60
Average length of summer periods..... days..	168	168	168
Average gain per calf, summer..... pounds..	193	192	182
Cost per day, summer.....	\$0.033	\$0.033	\$0.033
Average total cost per year.....	\$17.21	\$15.75	\$23.67
Average total gains per calf..... pounds..	247	239	280
Cost per pound yearly gain.....	\$0.07	\$0.066	\$0.084

SUMMARY OF COSTS.

1. Corn silage and clover hay, fed to Lot 2, was the cheapest ration used and cost the least per pound of yearly gain.

2. Lot 3, fed mixed hay and grain, made a large gain but cost \$6.46 more per year per calf than Lot 1, and \$7.92 more per year per calf than Lot 2. Therefore, a ration containing silage for wintering

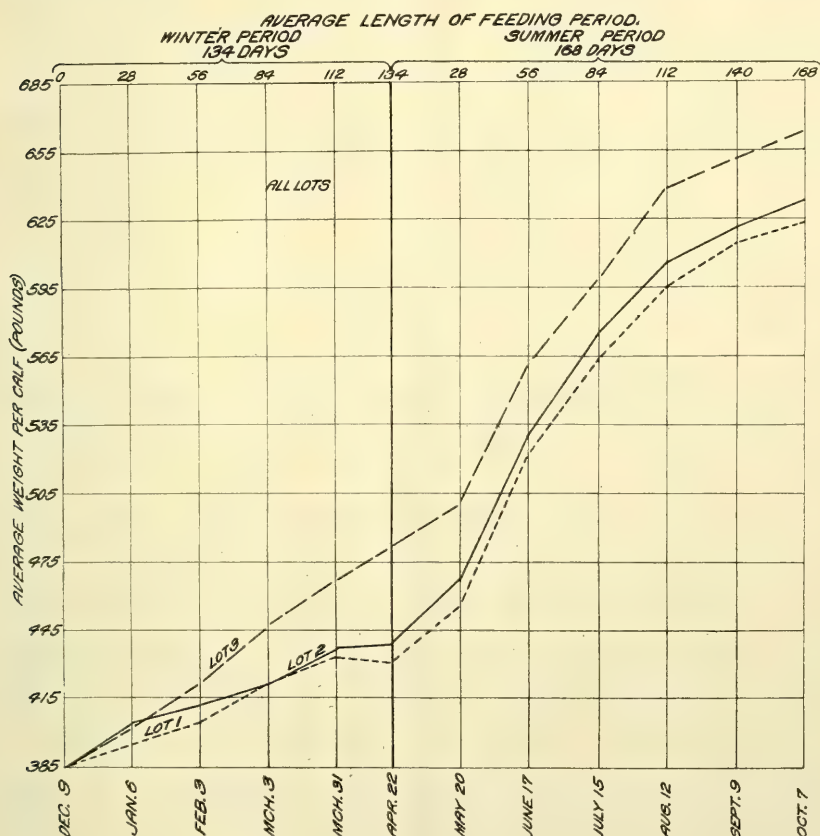


FIG. 9.—Average results of winter and summer (grass) feeding for the 3 lots fed in winter, as follows: Lot 1—Corn silage, 12.3 pounds; rye hay, 3.9 pounds; cottonseed meal, 0.6 pound. Lot 2—Corn silage, 12.3 pounds; clover hay, 4.9 pounds. Lot 3—Mixed hay, 9.2 pounds; grain mixture, 2.6 pounds.

steer calves is more economical than dry roughage with grain, considering the gains made both during the winter and in the summer following.

3. The cost of wintering a steer calf is approximately two-thirds the cost of keeping the calf one year. The profit, therefore, is determined largely by the cost of the winter ration.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY
▽

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1043



Contribution from the Office of Farm Management and
Farm Economics
G. W. FORSTER, Acting Chief

Washington, D. C.

January 23, 1922

CROP INSURANCE: RISKS, LOSSES, AND PRINCIPLES OF PROTECTION.

By V. N. VALGREN, *Associate Agricultural Economist.*

CONTENTS.

	Page.		Page.
The farmer's "independence"-----	1	Elimination or reduction of risk-----	13
Meaning of "loss" or "damage" in connection with growing crops---	2	Self-insurance-----	13
Quantitative importance of annual damage to farm crops-----	5	Insurance by contract-----	16
		Principles of crop insurance-----	18
		Summary-----	26

THE FARMER'S "INDEPENDENCE."

The farmer is frequently spoken of as the most independent member of organized society. Using the word "independent" in its social significance, this characterization is essentially true. Certainly the land-owning farmer is less directly dependent than those who follow commercial or professional pursuits upon the good will of his fellow-men and under less obligation to cater to their whims or prejudices. But though the farmer enjoys a comparatively high degree of independence in his social and business relations, his economic status, to an unusual degree, is directly dependent upon nature.

The factory, the mill, the store, or the business of the professional man may continue, for a time at least, but little disturbed by adverse weather conditions or other natural agencies that endanger farm crops. Only when these conditions or agencies cause the failure of crops over wide areas are commercial and professional men affected severely. Assuming, however, that the farmer brings to his work reasonable effort and good judgment, favorable action of natural forces and agencies means a large harvest, while adverse action by one or more of them may nullify his best efforts. Excessive heat or rain may ruin his planted fields, his gardens, or his orchards, as may also the lack of heat or the coming of drought.

His growing grain or fruit may be injured by plant diseases, devoured by insect or animal pests, or severely damaged by windstorms, frost, or hail.

MEANING OF "LOSS" OR "DAMAGE" IN CONNECTION WITH GROWING CROPS.

Before attempting to make any statement concerning the importance or extent of loss or damage to farmers resulting from adverse natural conditions or agencies, the meaning of the words "loss" or "damage" when used in connection with crops must be determined. One or two simple illustrations will assist in giving these terms a more definite meaning than the one often attached to them.

Assume, for example, that with ideal climatic conditions and in the absence of all loss-producing agencies, A, B, and C, farmers in different sections of the country, can produce, respectively, 40 bushels of wheat, 100 bushels of corn, and 800 pounds of lint cotton an acre. Each man has at some time produced the exceptionally large yields indicated. Because the conditions are not ideal during a given season, A actually harvests only 20 bushels of wheat an acre, B only 55 bushels of corn, and C only 350 pounds of cotton. Taking into consideration the loss due to damage to crops from all causes or combinations of causes, these three farmers, in a certain sense at least, may claim losses of 20 bushels of wheat, 45 bushels of corn, and 450 pounds of cotton an acre, respectively. They failed by the amounts indicated to obtain the maximum crops that would have resulted from the expenditure of their labor and capital had not weather conditions and other natural agencies been to some extent adverse.

As the natural hazards to crops are exceptionally high in certain types of farming, such as wheat production in the semiarid West, the next illustration may very properly be based on this type of farming. Let it be assumed that farmers X, Y, and Z are engaged during a given year in producing wheat by dry-farming methods in three semiarid regions of the West, and that the average yield of wheat in each of these regions for the last 20 years has been 8 bushels an acre. Let it be assumed also that this average yield has, at the price received, given returns covering all proper charges against the production of an acre of wheat under the methods of tillage followed by these men. On each of the farms in question 35-bushel yields have been harvested, Y having reaped a 35-bushel crop a year ago.

In the territory where X operates, average conditions prevail throughout the year in question. X grows and actually reaps an 8-bushel crop. In Y's territory the season proves extremely adverse, a

late spring frost followed by drought causing his crop to be a total failure. Finally, in the territory where Z is farming, climatic and other conditions prove highly favorable during the greater part of the season. Until within two weeks of harvest time, Z figures that he has a 35-bushel crop in prospect. At that time, however, a hail-storm passes over his farm and destroys 60 per cent of his crop, resulting in an actual yield of 14 bushels an acre instead of 35 bushels.

Limiting consideration to the returns for the single year and speaking this time first in terms of actual income rather than prospective income, farmer X, who grew and harvested an 8-bushel crop, had neither a profit nor a loss. He reaped an amount which at the price received was equivalent to his entire costs chargeable to the season's crop. On the other hand, farmer Y, who, because of frost and drought reaped no harvest whatever, suffered a loss equivalent to his entire expenditure of labor and capital chargeable to the year's operations. Farmer Z, with his 14-bushel yield, in spite of the damage to his crop by hail, realized a profit.

If, however, the matter is considered from the point of view not of actual income but of prospective yield and income, as was done in the first illustration, the situation changes. Had it not been for drought, excessive heat, untimely frost, hail, or some other cause or combination of causes, X, Y, and Z would each have reaped a 35-bushel yield. In a certain sense, therefore, all may claim to have suffered loss. This becomes more apparent in the case of farmer Z, who had in immediate prospect a 35-bushel yield when he suddenly suffered a 60 per cent damage by hail, in consequence of which he claimed a loss of 21 bushels an acre. He actually reaped a harvest of 14 bushels an acre, while his cost of production was only the equivalent of 8 bushels an acre. Nevertheless, if Z had carried hail insurance on his crop he would have been entitled to indemnity, under the prevailing plan of settlement, equivalent to 60 per cent of his insurance an acre. It must be conceded, therefore, that Z suffered a recognized form of loss, even though the loss related to wheat in prospect rather than to wheat already in existence and in spite of the fact that his hail-damaged crop yielded him a material profit over and above his cost of production. The fact that the loss or damage suffered by Z on his crop was sudden and spectacular does not make it materially different from the losses or damages suffered by X and Y. In each case it was wheat in prospect and not wheat in actual existence that was lost. At the time of planting the prospects of a perfect yield may have been equally good for each of the three men. The prospects of X were early reduced by certain natural causes; those of Y were entirely eliminated also in the early part of the season; while those of Z continued good until near harvest time, when they were suddenly reduced.

From these illustrations it becomes apparent that the word "loss" in connection with crops may have either of two different meanings. The kind of loss suffered by Z when his prospective 35-bushel wheat crop was reduced by a hailstorm to a 14-bushel crop, as well as the less spectacular but more severe loss which caused the prospects of X to shrink from 35 to 8 bushels an acre, is perhaps best termed "crop damage" by way of distinguishing it from the kind of loss suffered by Y, which was not only crop damage or a diminution in prospective yield, but a "financial loss" on the season's operations.

Adhering to this terminology, it may be said that X and Z suffered crop damage on their wheat, which, however, was not sufficiently severe to prevent X from breaking even, or Z from making a profit on the year's operations. Y, on the other hand, suffered crop damage which resulted in a financial loss equal to his entire expenditures in connection with the crop which failed to yield a harvest. Similarly A, B, and C, in the first illustration, with their harvests of 20 bushels of wheat, 55 bushels of corn, and 350 pounds of cotton, respectively, suffered crop damage, although each may have been able to show a financial profit instead of a financial loss on his year's operations.

Even after this attempt at clarification, one of the terms, "crop damage," retains a vagueness which it seems impossible entirely to remove. The idea of crop damage set forth in the preceding paragraphs may be said to be faulty in that it assumes that the best crop yet harvested was a perfect or no-damage crop, whereas it may well be questioned if on any farm such a crop has yet been reaped. It must be further conceded that it would be impracticable to arrive at any figures representing the crop damage for a larger area or for the country as a whole by using the term as outlined, since it would be impossible to take into consideration the maximum yield on each individual farm.

In order to obviate these difficulties and to make it possible to work out approximate figures for the amount of crop damage from various causes, the United States Department of Agriculture has arbitrarily assumed that a crop exceeding by 10 per cent the normal yield is a perfect or no-damage crop for the territory in question. The normal yield may, in turn, be defined as the yield that the crop reporter has in mind as one which in good years actually occurs over extended areas, and in percentages of which he reports crop prospects as well as crop damages from the different causes. The raising of the normal yield by 10 per cent in order to determine the no-damage yield is an attempt to make suitable allowance for the fact that the yield which the crop reporter, as the result of experience and observation, has in mind as a normal yield for his locality is not strictly a perfect or no-damage yield. The difference between a perfect or no-damage yield and the actual yield is the measure of total crop damage.

QUANTITATIVE IMPORTANCE OF ANNUAL DAMAGE TO FARM CROPS.

About 12 years ago the United States Department of Agriculture began to require of its thousands of crop reporters in all parts of the United States estimates of the percentage of damage caused to leading crops from specified causes. The crops covered are corn, wheat, oats, barley, flaxseed, rice, potatoes, tobacco, hay, and cotton. The percentage of damage from the various causes and the quantitative damage, calculated by applying the standard for a perfect or no-damage crop indicated above, are given in condensed form in

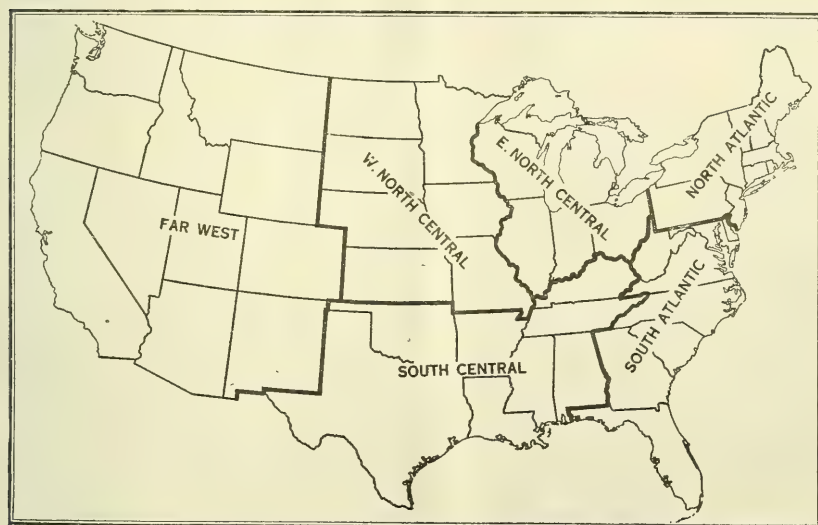


FIG. 1.—Geographic divisions to which figures in Tables 1 and 2 apply.

Tables 1 and 2, respectively. Table 3 gives value figures obtained by applying to the quantitative figures the price per unit prevailing during each year. While all three tables give damage by the same specified causes for each of the crops enumerated, Tables 1 and 2 give in percentages and in quantitative units, respectively, *average annual damage* during the decade, 1909–1918, by geographic divisions, as well as for the country as a whole. Table 3, on the other hand, expresses the damage during each year from 1909 to 1919, inclusive, in terms of dollars; all the figures in this table applying to the country as a whole.

The geographic divisions here used are designated as North Atlantic, South Atlantic, East North Central, West North Central, South Central, and Far West (fig. 1).

TABLE 1.—Average annual crop damage from specified causes, in percentage of normal yield, by geographic divisions, for decade 1909–1918.^a

Crop and geographic division.	Adverse weather conditions.									Plant diseases.	Insect pests.	Animal pests.	Other and unknown. ^c
	Total loss.	Deficient mois- ture.	Excessive mois- ture.	Floods.	Frost.	Hail.	Hot winds.	Storms.	Other climatic. ^b				
Corn:													
North Atlantic.....	24.14	9.58	4.55	0.18	3.57	0.36	0.20	0.61	0.70	0.16	2.23	0.17	1.83
South Atlantic.....	21.07	9.62	4.31	1.24	.63	.33	.39	.64	.24	.27	2.28	.15	.97
East North Central.....	28.73	11.04	4.79	.75	4.65	.25	1.43	.64	.43	.15	2.88	.10	1.62
West North Central.....	36.38	19.22	3.64	.68	3.64	.69	3.27	.30	.51	.14	2.77	.23	1.29
South Central.....	34.62	20.98	3.31	1.28	.60	.34	2.80	.73	.34	.37	2.76	.15	.96
Far West.....	29.89	17.51	.73	.29	3.43	1.12	.72	.12	.50	.49	2.94	.96	1.08
Total.....	31.99	16.19	4.00	.88	2.85	.44	2.29	.52	.44	.22	2.70	.17	1.29
Wheat:													
North Atlantic.....	16.81	3.37	1.36	.14	1.29	.24	.15	.16	5.18	.47	3.15	.03	1.27
South Atlantic.....	17.61	4.64	2.21	.39	.96	.47	.24	.27	3.12	2.23	1.54	.06	1.48
East North Central.....	23.06	3.59	2.28	.38	.82	.20	.44	.16	9.51	.77	3.88	.01	1.02
West North Central.....	33.04	14.59	2.33	.35	.48	1.49	2.99	.30	3.79	3.92	2.02	.11	.67
South Central.....	32.17	18.09	2.63	.44	.33	.72	1.60	.19	2.71	1.48	2.67	.09	1.22
Far West.....	23.48	12.96	.77	.24	1.32	1.22	1.42	.29	1.81	1.21	6.67	.82	1.80
Total.....	28.77	12.38	2.03	.33	.70	1.10	2.02	.26	4.13	2.65	2.12	.19	.86
Oats:													
North Atlantic.....	17.47	7.94	3.85	.15	.17	.32	.43	.49	.54	1.70	.54	.03	1.31
South Atlantic.....	23.82	9.50	2.10	.54	.79	.17	.21	.21	6.10	1.89	.41	.06	1.84
East North Central.....	20.66	10.76	3.38	.35	.16	.26	1.42	.57	.39	1.42	.82	.01	1.12
West North Central.....	26.76	15.05	2.43	.25	.40	1.17	2.83	.38	.40	2.04	.95	.06	.80
South Central.....	32.53	19.61	2.83	.58	.49	.47	1.18	.32	2.07	1.73	1.49	.06	1.70
Far West.....	22.68	13.72	1.00	.11	1.15	1.60	1.08	.30	.59	.90	6.63	.68	.92
Total.....	24.52	13.44	2.73	.31	.38	.77	1.90	.43	.80	1.73	.89	.08	1.06
Barley:													
East North Central.....	15.35	6.50	2.75	.16	.31	.30	2.17	.52	.34	.66	.32	.01	1.31
West North Central.....	33.90	20.12	1.76	.16	.64	1.81	4.19	.42	.38	2.28	.94	.16	1.04
Far West.....	20.48	13.60	1.25	.10	.97	.44	.94	.15	.60	.39	.37	.73	.94
Total.....	28.65	17.06	1.78	.14	.68	1.32	3.17	.36	.43	1.65	.74	.27	1.05
Flaxseed: Total.....													
	36.44	21.06	1.25	.14	3.97	1.72	3.04	.22	.39	2.19	.95	.09	1.42
Rice:													
South Central.....	19.77	7.20	3.24	1.52	.25	.02	.36	2.01	.23	1.22	.79	.24	2.69
California.....	8.43	1.34	.77	.....	.42	.....	1.43	.10	.28	.....	.....	.67	3.42
Total.....	19.04	6.67	3.14	1.47	.24	.02	.43	1.85	.23	1.18	.76	.29	2.76
Potatoes:													
North Atlantic.....	29.46	10.23	4.21	.12	1.36	.05	.40	.04	.48	8.02	2.98	.03	1.54
South Atlantic.....	28.28	15.51	1.96	.34	.71	.14	.38	.04	.31	2.86	3.68	.08	2.27
East North Central.....	31.08	14.53	3.78	.29	2.19	.04	.83	.04	.47	4.31	3.15	.01	1.44
West North Central.....	33.35	20.00	3.01	.33	.96	.30	1.28	.04	.49	1.96	3.79	.06	1.13
South Central.....	32.66	18.62	2.35	.35	.91	.17	.65	.06	.41	1.11	5.58	.05	2.40
Far West.....	23.75	11.15	.62	.16	2.77	.26	.57	.06	.48	3.62	1.31	.42	2.33
Total.....	30.12	14.55	3.08	.25	1.57	.14	.73	.04	.45	4.35	3.23	.08	1.65
Tobacco:													
North Atlantic.....	15.05	6.34	1.29	.18	1.79	2.17	.07	.55	.46	.22	1.12	.01	.85
South Atlantic.....	21.38	8.75	4.01	.66	.41	.75	.15	.51	.40	.54	3.54	.01	1.65
East North Central.....	19.26	6.72	3.16	.37	3.33	1.13	.21	.36	.34	.45	1.72	(d)	1.47
South Central.....	21.33	9.84	4.03	.81	.65	.44	.25	.13	.42	.28	2.35	.01	2.12
Total.....	20.50	8.72	3.65	.64	1.02	.81	.19	.34	.39	.40	2.59	.01	1.74
Hay:													
North Atlantic.....	16.50	10.08	1.50	.09	.92	.05	.25	.12	1.53	.09	.45	.01	1.41
South Atlantic.....	21.27	14.28	2.01	.66	.38	.15	.32	.17	1.06	.13	.30	.04	1.77

^a The statistical data contained in this table and in Tables 2 and 3 were gathered, tabulated, and computed by the Bureau of Crop Estimates, which has recently been combined with the Bureau of Markets, as the Bureau of Markets and Crop Estimates.

^b Including winterkill.

^c Including defective seed.

^d Less than 0.005 of 1 per cent.

TABLE 1.—Average annual crop damage from specified causes, in percentage of normal yield, by geographic divisions, for decade 1909-1918—Continued.

Crop and geographic division.	Total loss.	Adverse weather conditions.								Plant diseases.	Insect pests.	Animal pests.	Other and unknown.
		Deficient mois- ture.	Excessive mois- ture.	Floods.	Frost.	Hail.	Hot winds.	Storms.	Other climatic.				
Hay—Continued.													
East North Central	19.01	10.89	1.99	.27	.71	.04	.53	.14	2.27	.09	.57	.01	1.50
West North Central	24.89	19.11	1.52	.36	.20	.17	1.03	.09	1.30	.05	.40	.03	.63
South Central.....	22.10	14.63	2.61	.61	.19	.07	.72	.21	.79	.13	.23	.02	1.89
Far West.....	18.91	11.88	1.33	.25	1.16	.25	.42	.22	.77	.17	1.00	.46	1.00
Total.....	20.35	13.44	1.74	.31	.62	.11	.58	.15	1.45	.10	.52	.08	1.25
Cotton:													
South Atlantic....	27.09	6.60	6.75	1.10	1.99	.48	.99	.60	.77	3.03	2.85	(a)	1.93
South Central.....	38.83	14.53	3.42	1.03	1.05	.48	1.75	.75	.57	1.61	12.35	.03	1.26
Total.....	35.49	12.29	4.34	1.05	1.32	.48	1.56	.71	.60	2.00	9.67	.02	1.45

^a Less than 0.005 of 1 per cent.

The purpose of Table 1 is to bring out the relative degree of severity of the different hazards, or causes of damage, with reference to each of the crops enumerated for the country as a whole as well as for the various geographic divisions. Thus, in the case of corn, deficient moisture represented the most severe hazard during the 10-year period, not only for the country as a whole, but also for each of the geographic divisions. Excessive moisture represented the second most severe hazard for the country and for four of the six geographic divisions. Frost was the third most severe hazard, insect pests the fourth, and hot winds the fifth, considering the country as a whole. None of the other specified causes represented as much as 1 per cent of damage for the entire country, although the damage or loss from floods exceeded this amount in the South Atlantic and South Central States, and hail damage was more than 1 per cent of the crop damage in the Far Western States.

The purpose of Table 2 is to show quantitative damages on a plan similar to that by which damages are given on a percentage basis in Table 1. The figures in Table 2, therefore, represent not only the relative severity of the hazards or causes of damage in each case, but also the importance, from the point of view of acreage or volume, of the given crop, in the division or in the entire country as the case may be. This explains why some causes of loss appear relatively important for given crops in certain divisions in Table 1 and relatively unimportant for the same crop in the same divisions in Table 2. According to Table 1, for example, an average of 1.12 per cent of the corn crop was lost annually in the far western division through the occurrence of hail, which was a higher percentage of hail damage

than occurred to this crop in any other division. But according to Table 2, owing to the relative unimportance of the corn crop in this division, the total hail damage was only 300,000 bushels, or less than it was in any other division.

TABLE 2.—Average annual crop damage from specified causes, in bushels, pounds, or tons, by geographic divisions, for decade 1909-1918.

[In millions of bushels or pounds, and thousands of tons.]

Crop and geographic division.	Total loss.	Adverse weather conditions.							Plant diseases.	Insect pests.	Animal pests.	Other and unknown. ^b	
		Deficient mois- ture.	Excessive mois- ture.	Floods.	Frost.	Hail.	Hot winds.	Storms.					Other climatic. ^a
Corn (bushels):													
North Atlantic.....	31.9	12.3	6.3	0.2	4.9	0.5	0.3	0.8	0.9	0.2	2.9	0.2	2.4
South Atlantic.....	87.2	39.8	17.5	5.1	2.8	1.4	1.6	2.7	1.1	1.1	9.5	.6	4.0
East North Central.....	317.4	120.8	53.0	8.3	53.0	2.8	15.5	7.0	4.8	1.7	31.6	1.1	17.8
West North Central.....	588.0	310.8	57.1	10.8	61.4	11.2	52.3	4.7	8.3	2.3	44.5	3.8	20.8
South Central.....	313.7	189.0	31.7	11.5	5.0	2.8	24.9	6.7	3.4	3.5	24.6	1.4	9.2
Far West.....	7.3	4.3	.2	.1	.8	.3	.2	(c)	.1	.1	.7	.2	.3
Total.....	1,345.6	677.0	165.8	36.1	127.9	19.0	94.8	22.0	18.5	8.9	113.8	7.3	54.5
Wheat (bushels):													
North Atlantic.....	6.9	1.3	.6	.1	.5	.1	.1	.1	2.2	.2	1.3	(c)	.4
South Atlantic.....	8.9	2.3	1.1	.2	.4	.3	.1	.1	1.8	1.1	.8	(c)	.7
East North Central.....	35.1	6.1	3.6	.6	1.3	.3	.8	.3	12.7	1.2	6.5	(c)	1.7
West North Central.....	179.3	77.4	13.9	2.0	2.6	8.3	16.5	1.7	18.5	22.5	11.6	.6	3.7
South Central.....	27.5	14.5	2.7	.4	.2	.7	1.2	.2	2.6	1.4	2.5	.1	1.0
Far West.....	43.5	24.5	1.3	.4	2.3	2.2	2.7	.5	3.3	2.2	1.2	1.5	1.4
Total.....	301.2	126.2	23.1	3.8	7.4	11.9	21.4	2.8	41.0	28.6	23.8	2.1	9.1
Oats (bushels):													
North Atlantic.....	19.9	9.1	4.4	.2	.2	.3	.5	.6	.6	1.9	.6	(c)	1.5
South Atlantic.....	11.5	4.6	1.0	.3	.4	.1	.1	.1	3.0	.9	.2	(c)	.8
East North Central.....	109.6	57.0	17.9	1.9	.9	1.4	7.5	3.0	2.0	7.6	4.3	.1	6.0
West North Central.....	202.7	114.9	17.8	1.8	3.0	8.9	21.5	2.9	3.0	15.4	7.2	.5	5.8
South Central.....	42.7	25.3	3.7	.8	.6	.7	1.4	.4	3.0	2.4	2.2	.1	2.1
Far West.....	27.9	16.9	1.2	.1	1.4	2.0	1.3	.4	.7	1.1	.8	.8	1.2
Total.....	414.3	227.8	46.0	5.0	6.5	13.4	32.3	7.3	12.5	29.2	15.3	1.5	17.5
Barley (bushels):													
East North Central.....	5.4	2.3	.9	.1	.1	.1	.8	.2	.1	.2	.1	(c)	.5
West North Central.....	51.4	30.9	2.6	.2	1.0	2.7	6.3	.6	.6	3.4	1.4	.2	1.5
Far West.....	17.2	11.5	1.0	.1	.8	.4	.8	.1	.5	.3	.3	.6	.8
Total.....	74.1	44.7	4.5	.4	1.9	3.2	7.8	.9	1.2	4.0	1.9	.8	2.8
Flaxseed (bushels), total.....	10.2	6.0	.3	(c)	1.1	.5	.8	.1	.1	.6	.3	(c)	.4
Rice (bushels):													
South Central.....	6.9	2.6	1.2	.5	.1	(c)	.1	.6	.1	.4	.3	.1	.9
California.....	.4	.1	(c)	.....	(c)	.....	.1	(c)	(c)	.....	.....	(c)	.2
Total.....	7.4	2.7	1.3	.6	.1	(c)	.1	.7	.1	.4	.3	.1	1.0
Potatoes (bushels):													
North Atlantic.....	47.2	16.2	6.8	.2	2.2	.1	.6	.1	.7	13.0	4.8	(c)	2.5
South Atlantic.....	10.2	5.5	.7	.1	.3	.1	.1	(c)	.1	1.1	1.4	(c)	.8
East North Central.....	44.3	20.6	5.4	.4	3.2	.1	1.2	.1	.6	6.1	4.5	(c)	2.1
West North Central.....	36.4	21.9	3.2	.4	1.1	.3	1.4	(c)	.5	2.2	4.1	.1	1.2
South Central.....	9.9	5.7	.7	.1	.3	.1	.2	(c)	.1	.3	1.7	(c)	.7
Far West.....	16.9	8.1	.4	.1	1.9	.2	.4	(c)	.3	2.6	.9	.3	1.7
Total.....	164.8	78.0	17.2	1.3	8.9	.8	3.9	.2	2.5	25.3	17.4	.5	8.8

^a Including winterkill.

^b Including defective seed.

^c Less than 50,000 bushels.

TABLE 2.—Average annual crop damage from specified causes, in bushels, pounds, or tons, by geographic divisions, for decade 1909-1918—Continued.

[In millions of bushels or pounds, and thousands of tons.]

Crop and geographic division.	Total loss.	Adverse weather conditions.								Plant diseases.	Insect pests.	Animal pests.	Other and unknown.*
		Deficient moisture.	Excessive moisture.	Floods.	Frost.	Hail.	Hot winds.	Storms.	Other climatic.				
Tobacco (pounds):													
North Atlantic.....	19.1	7.9	1.6	.2	2.4	2.8	.1	.7	.6	.3	1.4	(a)	1.1
South Atlantic.....	114.1	43.6	22.3	3.9	2.4	4.4	.8	3.0	2.2	2.9	19.8	(a)	8.8
East North Central.....	39.5	13.8	6.5	.8	6.8	2.3	.4	.7	.7	.9	3.6	(a)	3.0
South Central.....	123.6	53.7	25.1	5.1	3.9	2.7	1.3	.8	2.5	1.7	14.1	.1	12.6
Total.....	296.3	119.0	55.4	10.0	15.6	12.1	2.7	5.3	5.9	5.8	38.9	.1	25.5
Hay (tons):													
North Atlantic.....	3,128	1,927	278	18	172	11	48	23	282	16	85	2	266
South Atlantic.....	1,043	690	100	34	18	9	16	9	57	6	16	1	87
East North Central.....	4,258	2,431	441	58	159	9	117	32	527	21	128	2	333
West North Central.....	6,441	4,922	401	99	53	47	260	26	349	11	104	7	162
South Central.....	1,704	1,157	181	44	13	5	54	16	64	10	19	1	140
Far West.....	3,839	2,414	266	49	241	51	84	45	157	35	206	90	201
Total.....	20,414	13,542	1,667	301	657	131	580	151	1,436	100	557	103	1,189
Cotton (pounds):													
South Atlantic.....	870.4	213.3	214.8	35.4	64.8	15.4	31.8	19.7	24.3	95.9	93.8	.1	61.1
South Central.....	2,860.6	1,078.7	249.8	74.5	75.7	35.0	129.2	53.1	42.1	114.2	912.6	2.4	93.3
Total.....	3,731.0	1,292.0	464.6	109.9	140.5	50.4	161.0	72.8	66.5	210.1	1,006.3	2.4	154.5

(a) Less than 50,000 pounds.

Based on quantitative measurements and considering the country as a whole, deficient moisture is again the leading cause of crop damage to each of the crops here covered, excessive moisture ranking second for corn, oats, rice, tobacco, and hay. In the case of wheat, plant disease is the second most important cause of damage, with insect pests third, and these causes also retain this relative importance in potatoes. In the case of barley, hot winds come second as a source of damage, while with cotton insect pests occasion almost as much damage on the average as does deficient moisture.

The figures in Table 3 indicate that, considering a crop which is 10 per cent above the normal as a perfect or no-damage crop, and applying average farm prices to the quantitative losses of each crop for each year, this total annual crop damage in the United States to the crops here considered varied during the 11 years 1909 to 1919, inclusive, from a minimum of 2,054 million dollars in 1912 to a maximum of nearly 3,066 million dollars in 1918. The average annual crop damage during the 11-year period was 2,620 million dollars. These loss figures in terms of dollars are particularly convenient in making comparisons, but, for reasons stated on page 12, they do not represent the actual monetary loss to farmers through a reduction of the yield.

TABLE 3.—Annual crop damage from specified causes in the United States, for the 11 years, 1909 to 1919, inclusive.

[In millions of dollars.]

Crop and year.	Adverse weather conditions.										Plant diseases.	Insect pests.	Animal pests.	Other and unknown. ^b
	Total loss.	Deficient mois- ture.	Excessive mois- ture.	Floods.	Frost.	Hail.	Hot winds.	Storms.	Other climatic. ^a					
Wheat:														
1909.....	240.7	81.4	35.8	7.4	4.0	21.3	12.3	6.7	28.2	17.5	12.5	2.8	10.8	
1910.....	378.9	205.4	10.0	1.7	10.0	6.1	27.8	1.8	69.3	9.0	24.4	4.3	9.1	
1911.....	454.2	294.8	9.6	.1	19.5	4.9	46.9	.7	4.9	23.2	28.8	2.0	18.8	
1912.....	328.4	91.3	19.9	3.4	13.5	18.1	20.1	4.3	97.3	19.9	24.5	3.8	12.3	
1913.....	303.2	184.9	4.8	2.1	8.3	8.4	22.4	3.0	21.2	3.6	28.7	1.5	14.3	
1914.....	271.6	88.9	19.7	2.0	4.9	13.4	38.0	3.3	12.1	42.4	36.3	1.5	9.1	
1915.....	308.4	17.6	119.0	16.5	6.3	23.8	1.7	5.8	13.5	36.9	56.2	1.8	9.3	
1916.....	498.0	89.8	47.8	8.3	8.3	16.9	33.0	2.7	72.3	151.4	51.2	1.3	12.0	
1917.....	397.1	205.2	6.2	1.4	5.6	10.7	17.8	2.0	123.7	8.7	8.7	1.2	5.9	
1918.....	393.2	224.8	4.6	2.0	8.0	16.1	30.6	3.3	52.8	22.8	16.4	4.0	7.8	
1919.....	685.0	219.1	114.8	8.3	9.8	14.3	50.7	5.4	19.0	187.0	46.3	1.3	9.0	
Corn:														
1909.....	887.3	392.1	215.2	44.6	30.5	15.4	45.4	21.7	7.3	6.8	69.9	10.7	27.7	
1910.....	825.8	442.8	94.5	24.1	29.0	11.8	50.0	15.6	7.4	7.1	75.1	12.4	56.0	
1911.....	1,083.4	750.6	51.7	.1	14.8	6.2	109.2	1.8	18.2	7.9	73.4	5.2	44.3	
1912.....	858.6	277.2	150.1	29.8	54.7	15.2	31.4	9.0	16.8	8.9	158.4	11.3	95.8	
1913.....	1,213.9	851.3	25.1	10.2	24.7	12.0	119.3	13.0	10.8	1.2	112.5	2.6	31.2	
1914.....	961.5	652.6	40.1	11.5	11.4	16.0	66.2	11.9	7.0	3.3	115.0	2.9	23.6	
1915.....	963.0	97.4	384.5	65.6	202.5	20.2	7.4	39.2	35.1	8.5	70.1	2.7	29.8	
1916.....	1,103.5	570.9	190.8	63.7	51.1	12.2	52.3	40.2	13.1	9.9	64.8	3.3	31.2	
1917.....	1,187.8	446.9	100.1	20.3	447.0	21.6	43.0	12.3	15.7	10.0	51.8	2.4	17.3	
1918.....	1,189.3	715.3	29.1	17.9	58.2	12.5	184.0	11.0	8.8	8.9	82.2	2.7	58.7	
1919.....	765.3	321.6	221.8	41.9	4.8	8.0	28.3	14.0	4.1	11.0	93.0	2.6	14.2	
Oats:														
1909.....	154.1	55.9	35.7	4.0	4.1	7.3	6.1	5.6	3.3	16.9	3.8	.7	16.7	
1910.....	176.7	124.4	6.0	1.1	4.3	3.1	12.1	2.6	3.2	7.1	4.8	1.3	6.7	
1911.....	291.1	202.7	8.0	.1	3.5	2.4	37.3	.7	6.1	5.5	10.6	.9	13.3	
1912.....	134.3	52.3	25.2	2.4	3.2	7.3	7.5	3.6	4.6	12.6	5.2	1.3	9.1	
1913.....	231.7	173.3	5.8	1.4	1.6	4.8	13.4	1.9	5.7	4.1	8.2	.6	10.9	
1914.....	212.3	121.4	17.6	1.4	1.8	6.1	19.5	3.3	3.5	14.7	13.0	.6	9.4	
1915.....	136.9	15.8	65.8	7.6	2.0	8.0	9.9	6.8	2.7	17.6	2.6	.5	6.6	
1916.....	230.5	88.7	33.9	3.4	2.5	7.0	21.5	4.3	8.0	40.4	11.9	.4	8.5	
1917.....	180.0	107.3	11.8	1.4	3.9	6.6	8.9	2.4	22.8	6.8	3.7	.4	4.0	
1918.....	188.6	118.8	4.8	1.5	4.6	7.8	15.6	2.8	9.4	9.8	7.8	.5	5.2	
1919.....	251.0	97.4	51.1	3.7	1.4	3.2	21.7	3.7	4.8	39.3	17.4	.3	5.0	
Barley:														
1909.....	38.7	15.8	6.0	.6	1.2	3.2	3.6	1.2	.7	2.2	.6	.9	2.7	
1910.....	70.8	55.7	.5	.1	1.4	1.3	6.5	.2	.7	.7	1.3	1.2	1.2	
1911.....	65.1	45.2	2.4	.....	1.5	.6	9.0	.1	.7	1.3	1.4	.6	2.3	
1912.....	33.7	14.5	3.8	.2	1.5	2.9	2.7	.9	1.1	1.4	.8	1.1	2.8	
1913.....	57.2	41.3	1.5	.1	.7	1.6	5.0	.5	1.2	.3	1.9	.3	2.8	
1914.....	36.8	13.5	4.1	.3	1.3	2.2	7.0	.7	.5	3.2	1.1	.5	2.1	
1915.....	17.2	2.7	5.1	.4	1.0	2.4	.8	.8	.3	1.6	.4	.4	1.3	
1916.....	50.5	14.9	5.4	.5	1.3	2.3	7.6	.8	2.0	12.6	1.1	.3	1.7	
1917.....	61.6	50.9	1.3	.1	1.8	2.0	4.6	.4	.4	1.1	.8	.3	.9	
1918.....	62.1	45.3	1.0	.2	1.5	2.2	4.6	.6	.6	1.3	3.1	.4	1.3	
1919.....	59.8	30.2	4.6	.7	.5	2.3	6.2	.4	.4	7.8	5.7	.3	.7	
Flaxseed:														
1910.....	40.2	31.5	.....	.....	1.6	.6	4.0	(c)	(c)	.8	1.2	.1	.4	
1911.....	25.9	11.7	.8	.....	5.9	.6	2.0	.1	.7	1.5	1.2	(c)	1.4	
1912.....	19.6	3.8	2.2	.2	4.4	2.0	.8	.6	.1	2.7	.3	.3	2.2	
1913.....	20.4	14.4	.4	.1	.6	1.0	1.3	.1	.3	1.0	.1	.....	1.1	
1914.....	12.4	4.8	.8	.1	.8	.8	2.8	.1	.1	.9	.2	.1	.9	
1915.....	7.0	.8	.7	.1	3.0	.8	.1	.1	.2	.....	(c)	.....	.3	
1916.....	6.6	1.3	.8	.1	.6	.6	1.1	.1	.1	1.5	.1	.....	.3	
1917.....	31.9	26.3	.2	(c)	1.5	.6	1.5	.....	.4	.6	.6	.....	.2	
1918.....	19.4	12.9	.1	(c)	1.6	1.2	1.2	.1	(c)	.5	1.3	.....	.4	
1919.....	24.5	15.5	.5	.3	.2	.7	1.4	(c)	(c)	1.3	4.3	(c)	.1	
Rice:														
1909.....	5.3	1.4	(c)	.....	.....	.4	2.0	.....	.8	.3	.1	.2	.2	
1910.....	6.4	2.6	.6	.....	.1	.....	(c)	.4	.....	1.2	.1	.4	.8	
1911.....	5.1	2.3	1.1	.....	.1	.....	.2	.....	(c)	.2	.2	.2	.7	
1912.....	7.2	1.1	.4	2.3	.....	.....	.2	.2	(c)	.9	.7	.2	1.1	
1913.....	12.0	1.6	6.0	2.5	.....	.....	(c)	.....	.....	(c)	.3	.....	1.6	
1914.....	6.2	1.9	.8	(c)	.....	(c)	.2	.2	.5	(c)	.5	(c)	2.1	

^a Including winterkill.^b Including defective seed.^c Less than \$50,000.

TABLE 3.—Annual crop damage from specified causes in the United States, for the 11 years, 1909 to 1919, inclusive—Continued.

[In millions of dollars.]

Crop and year.	Total loss.	Adverse weather conditions.							Plant diseases.	Insect pests.	Animal pests.	Other and unknown.
		Deficient moisture.	Excessive moisture.	Floods.	Frost.	Hail.	Hot winds.	Storms.	Other climatic.			
Rice—Contd.												
1909.....	8.3	3.0	.3	(a)	(a)	-----	.1	3.5	.2	.1	-----	.9
1910.....	3.9	2.1	.1		.1		.1	.1	.1	.5	-----	.7
1911.....	12.7	8.7		.1	.7	.1	(a)	(a)	(a)	.2	.1	.2
1912.....	12.2	4.0	.4	1.4	.1	-----	.2	.8	.2	.6	(a)	.9
1913.....	10.7	.5	6.7	.6	.2		(a)	1.3	.4	.2	.4	(a)
Potatoes:												
1909.....	96.6	50.6	13.2	1.5	7.7	.9	.8	.2	.6	7.8	7.9	4.9
1910.....	132.7	73.7	5.9	.8	5.2	.6	1.6	.1	1.6	15.0	21.5	6.0
1911.....	184.2	117.1	6.2	.1	5.6	.2	13.0	(a)	2.6	12.0	11.7	15.2
1912.....	97.6	26.2	13.6	1.5	2.6	.6	1.1	.3	1.7	26.9	16.1	6.3
1913.....	152.4	98.4	4.6	.7	8.5	.6	3.1	.2	3.0	6.3	16.6	10.1
1914.....	114.2	72.0	6.2	.6	3.0	.5	2.0	.1	1.3	5.8	14.1	8.4
1915.....	142.0	9.8	40.9	2.0	9.0	.6	.2	.3	1.3	62.1	11.1	4.5
1916.....	183.9	79.7	29.2	1.7	8.1	.9	5.5	.3	5.6	24.9	19.4	8.4
1917.....	130.3	47.6	19.7	1.2	15.1	1.0	1.6	.2	1.6	24.2	13.0	4.9
1918.....	149.9	77.2	5.3	1.0	8.1	.4	3.1	.2	1.5	28.6	17.5	6.8
1919.....	181.3	74.6	24.4	2.0	3.5	.5	3.4	.3	1.3	44.2	22.1	4.8
Tobacco:												
1909.....	40.1	11.9	13.3	2.1	1.4	1.8	.2	.4	.3	1.4	5.2	2.1
1910.....	43.5	10.4	14.3	2.6	.6	.7	.1	.3	1.6	1.4	5.9	5.6
1911.....	35.8	25.6	1.3	-----	2.3	.1	.9	(a)	.9	.5	1.5	2.7
1912.....	40.6	14.8	8.8	1.4	.9	2.1	.3	.5	.6	1.3	5.3	4.5
1913.....	45.4	26.0	1.6	.7	2.1	2.6	.5	1.3	.8	.3	6.1	3.4
1914.....	47.8	34.7	.4	.1	.6	1.2	.6	.3	.8	.1	5.6	3.3
1915.....	49.6	9.2	16.2	1.8	2.1	1.7	.3	2.0	1.0	1.3	8.6	5.4
1916.....	43.1	7.6	13.8	3.3	2.6	2.3	.2	2.1	1.1	.7	6.6	2.8
1917.....	36.6	7.6	5.9	1.2	7.4	3.0	.2	.5	1.0	.6	5.3	3.9
1918.....	34.1	18.5	1.4	.5	1.7	2.6	.4	.6	.4	1.0	5.6	1.4
1919.....	72.7	22.5	30.4	2.2	.7	2.9	.2	.7	.8	2.2	8.7	1.4
Hay: ^b												
1909.....	230.4	144.0	27.2	6.6	3.1	1.4	3.2	3.5	16.9	1.4	6.3	14.6
1910.....	294.3	215.7	14.1	3.4	8.5	1.2	5.6	.9	14.4	.9	6.9	20.3
1911.....	404.2	320.2	9.4	.2	11.6	1.2	21.9	-----	5.9	1.1	6.8	24.8
1912.....	185.7	52.7	60.6	7.2	16.8	2.1	1.3	4.5	12.8	3.0	7.8	15.8
1913.....	139.6	78.4	15.1	4.6	8.8	1.2	2.5	1.9	12.8	.6	4.2	9.0
1914.....	250.9	156.9	18.4	2.7	4.4	2.3	4.5	1.8	37.6	1.0	5.6	14.9
1915.....	345.5	242.0	11.1	2.7	9.5	1.7	10.9	1.4	34.7	1.3	12.9	16.6
1916.....	232.9	149.4	29.5	5.1	5.1	1.0	4.8	1.9	12.1	1.9	13.8	7.7
Cotton:												
1909.....	607.7	210.6	92.0	16.5	10.2	8.3	42.6	19.0	15.1	63.8	110.1	19.4
1910.....	540.8	181.2	82.8	13.4	31.0	4.0	19.3	2.2	10.9	67.5	109.3	18.7
1911.....	433.0	163.7	42.6	.2	4.7	1.5	26.6	6.3	10.3	7.9	128.9	39.9
1912.....	533.8	128.2	131.4	19.3	15.7	9.6	19.5	2.9	14.9	71.5	101.3	18.3
1913.....	582.9	263.3	34.8	14.4	18.2	8.0	41.1	8.9	12.2	8.5	152.0	21.4
1914.....	437.3	137.7	49.2	8.6	15.8	6.6	11.3	2.4	9.3	4.3	165.0	26.9
1915.....	543.1	104.3	83.8	27.9	8.2	9.4	16.9	28.3	9.4	29.1	173.9	51.5
1916.....	700.9	148.8	158.6	53.5	6.4	10.8	10.2	32.9	4.1	14.8	251.5	8.8
1917.....	632.6	232.8	28.3	8.3	98.2	17.0	10.7	3.0	6.7	22.4	191.6	13.6
1918.....	671.4	388.9	15.1	6.2	8.8	2.1	46.5	5.1	9.0	34.7	135.3	19.4
1919.....	660.9	43.1	241.5	26.4	3.8	3.7	7.0	7.9	2.2	22.5	294.4	8.4
Total:												
1909c.....	2,300.9	963.7	438.4	83.3	62.2	59.6	114.6	60.3	72.4	118.6	216.6	93.1
1910.....	2,510.1	1,343.4	228.7	47.2	91.7	29.4	127.0	24.1	109.1	110.7	250.5	124.8
1911.....	2,982.0	1,933.9	133.1	.8	69.5	17.7	267.0	9.7	50.3	61.1	264.5	163.4
1912d.....	2,053.8	609.4	355.4	60.5	96.5	57.8	83.6	22.9	137.1	146.1	312.6	152.4
1913d.....	2,619.1	1,654.5	84.6	32.2	64.7	39.0	206.1	28.9	55.2	25.3	326.4	96.8
1914d.....	2,100.1	1,127.5	139.2	24.6	39.6	46.8	147.6	22.3	35.1	74.7	350.8	85.8
1915.....	2,361.2	313.3	776.9	129.1	250.9	69.0	237.7	91.3	76.5	161.2	330.8	71.1
1916.....	2,960.5	1,082.2	495.5	139.1	89.8	54.2	134.0	85.4	119.2	260.3	410.9	83.4
1917.....	2,924.5	1,290.2	192.3	36.7	585.6	64.3	92.8	22.6	209.9	75.6	281.2	5.5
1918.....	3,065.7	1,847.7	76.5	33.4	102.1	46.6	297.1	25.9	117.2	109.1	282.7	8.8
1919.....	2,944.1	973.9	725.3	91.2	30.0	38.6	123.7	35.6	45.1	317.4	506.0	51.3

^a Less than \$50,000.^b Figures for 1912, 1913, and 1914 not available.^c Excluding flaxseed.^d Excluding hay.

An examination of the total damage to given crops indicates, as might be expected, a variation in most cases greater on a percentage basis than the variations in annual totals for all crops. These variations are particularly marked in the case of wheat, barley, flaxseed, and rice. They are smallest in the case of corn, owing largely, no doubt, to the general distribution of the corn acreage in the United States.

Lastly, an examination of the figures representing the damage to given crops from specified causes shows the relative variations to be even greater. Thus the variations in damage to the wheat crop from deficient moisture range from less than 18 million to 295 million dollars, while those of cotton from the same cause range from 43 million to nearly 389 million dollars. On a relative basis the variation in damage to individual crops from some of the less important causes would be still more striking. In the case of hail damage to cotton, for example, the variation is from 1½ million to 17 million dollars.

Deficient moisture and excessive moisture might also be expected to have an inverse relationship, the damage from one of these causes tending to be relatively light in years when the damage from the other is relatively heavy. This is well illustrated by the two columns given to these causes. Little, if any, relationship of this kind is noticeable, however, between the two causes of frost and hot winds which, in a modified way, also represent opposite extremes.

Extended comment on the tables seems unnecessary. It should be emphasized, however, that the figures for crop damage in terms of dollars represent, in part, a theoretical loss only. While an increase of 10 or 20 per cent in the yield of a given crop will increase the gross income of an individual farmer from that crop by the same percentage, this relationship between increase in yield and increase in gross income does not hold when all or even a large proportion of the entire farmer group is considered. In this case increase in yield will, of course, materially affect the total supply of the commodity in question, which naturally affects the price. No attempt has been made to allow for this fact in translating the quantitative crop damage into terms of dollars. Table 3, which shows damage to all crops in the common denominator of dollars, will, therefore, be of more value for purposes of making comparisons between the amount of damage to different crops and in different regions than as a measure of actual diminution in the income of the farmers by reason of damage to their crops.

ELIMINATION OR REDUCTION OF RISK.

SELF-INSURANCE.

While the individual farmer can not control the action of the weather or the elements, and frequently finds himself unable to combat the attacks of plant disease and insect pests, he can to a great extent reduce the losses that would result from the absence of proper care and forethought. In farming, as well as in other lines of activity, the old advice against putting all the eggs in one basket should be heeded as far as practicable. The single-crop farmer exposes himself to the possibility of losing the results of an entire year's work from a single catastrophe. Almost any one of the causes of crop damage enumerated in foregoing Tables 1, 2, and 3 may make his year's work a total loss. If, on the other hand, he invests part of his capital and labor in live stock, or in a variety of crops other than the main money crop of the region, it is highly improbable that the causes of loss affecting one of his investments will also seriously affect the others. The same plant diseases and insect pests rarely, if ever, affect all crops that can be grown in a given locality, and even damage from climatic causes, such as drought, excessive moisture, frost, or hail, rarely brings about a total destruction of all crops in a region. While all the crops in a given locality may be affected to some degree by each of these climatic contingencies, they probably will not be equally subject to damage from a given cause at the same time. In other words, the chances are that the critical period of one crop with reference to any one of these hazards will be past before the corresponding period of another crop is reached. Diversification, therefore, becomes a form of self-insurance.

The added safety to the farmer that lies in reasonable diversification of crops and products is becoming recognized to an increasing extent by country bankers, as well as by the farmers themselves. Many bankers in regions where a one-crop system has prevailed now insist as a condition to the granting of a loan to the farmer that he shall fill out and sign a credit statement, including an agreement to use a safe cropping system. This change of attitude on the part of banking interests, from one of encouraging the farmer to stake his success on a single crop to a position of urging him to play safe in so far as circumstances permit, represents an important advance in profitable relationship between the banker and the farmer.

A study of available information covering dates of the last killing frost in the spring and of the first killing frost in the fall, as well as that bearing on seasonal rainfall and temperature for his locality, will enable the farmer, within limits, to adjust the planting and hence the growing season of his crops in such a way as to incur a minimum of risk from these causes of crop damage. In

this connection should be mentioned the importance of reducing risks of loss by the careful selection for seed purposes of varieties of the different kinds of crops which mature within the space of the reasonably safe growing season of a given locality.

At Grand Rapids, Mich., for example, the average date of the last killing frost in the spring is May 11, while the average date of the first killing frost in the fall is about October 8. This gives an average growing season of 150 days for crops which are readily injured by frost. Weather Bureau records further indicate that five times in 20 years the date of the last killing frost in the spring had been 10 days or more later than the average, and, similarly, that four times in 20 years the date of the first killing frost in the fall had been 10 days or more earlier than the average date. The reasonably safe growing season for crops subject to damage by frost in this locality, therefore, is a little less than 130 days, covering a period from the last week in May to the last week in September. By adjustment of his dates of planting, as well as by the selection of the varieties of grains planted with careful regard to local climatic conditions as revealed by data covering extended periods of time, the farmer, in effect, can insure himself against frequent losses from frost. To a certain extent, he can also adjust his plan of farming to minimize the losses from drought and other climatic dangers.

Thus far we have considered only safeguards against forces which the farmer can not control and against which his only chance, with minor exceptions, is to adjust his business in such a way that the least possible danger will result from their adverse action. There are, however, many other causes of loss which can be directly eliminated or at least partially removed.

Loss from failure of seed to germinate can be eliminated to a great extent by planting only tested seed. This is particularly true in the case of crops, such as corn, where the germinating quality is frequently injured, even when the yield is bountiful and the crop, to all outward appearances, is sound. Individual plant diseases, such as smut in wheat, oats, and barley, may be eliminated by a single treatment of the seed before planting. In sections where wheat scab occurs this evil may be largely controlled by a system of rotation in which wheat never directly follows corn, unless the corn is cut for fodder and all litter removed or thoroughly covered by plowing in the fall. The elimination of black rust by the removal of the common barberry bush is a method of insuring against loss from this source. In the case of certain insect enemies, spraying or poisoning by one method or another may reduce or even eliminate their ravages. It is, of course, neither practical nor necessary to apply all preventive treatments at all times. The progressive farmer keeps himself informed as to the invasion of his region by any common disease or in-

sect pest and takes all available preventive measures against danger of loss or damage. Similar safety measures apply to many of the diseases that occasion losses among the farmer's live stock. By the timely application of vaccines, dipping, or other treatment many of the losses that threaten may be avoided.

As a final illustration of the reduction of risk by individual action, or self-insurance, the provision for a reserve against years when the income is materially less than the average may be mentioned. Many a farmer, who for one or more years has met with success and enjoyed a liberal income, recklessly assumes that each succeeding year will be equally profitable. On this assumption he expands his operations and strains his credit to the limit. A single year of failure may cause him to lose not only the results of that year's labor but very probably also his capital accumulated from the success of former years.

The reserve against lean years may be in the form of a savings account at the bank or a bond that is stable in value and readily marketable. A legal reserve life insurance policy with its loan and cash surrender features also constitutes a good emergency reserve in addition to the protection that it provides for dependents. In the case of the farmer with limited capital the suggested reserve may be given the form merely of an improved credit status. This may need a word of explanation.

Farmer D, who has already borrowed to the limit and has all his property pledged as security for loans, in a given year reaps a good harvest and receives good prices for his surplus products. Instead of reducing his indebtedness, after selling his crops, he renews such of his outstanding loans as expire, paying only the interest thereon. He then uses all his net income of the year to buy more land or other property, paying part cash and giving a mortgage on the newly acquired property for the balance. He has added to the property nominally his, but has improved his credit status little if at all. His margin of safety is no greater than it was before and he is about as likely to lose all he has by reason of a bad season as he was the year before.

Farmer E, on the other hand, whose property is also mortgaged to the limit before the reaping of a profitable harvest, uses his net income to reduce his outstanding debts. His live stock is cleared of mortgage and he makes a small prepayment on the mortgage on his farm. This man has added nothing to his outward possessions, but he has strengthened his hold on that which already was technically his. He has increased his margin of safety. In case of future need of loans he has security to offer. In other words, he has a form of reserve set aside from his prosperous year.

INSURANCE BY CONTRACT.

Tables 1, 2, and 3 give some idea at least of the extent of the hazards and the losses to which the producer of crops is exposed. Many of these hazards may be reduced or even eliminated by the principles of self-insurance already mentioned. Even after this is done, however, there remains a large element of risk in the production of crops which can be adequately cared for only by a reliable contract for indemnity, or, in other words, by insurance in the technical meaning of the term.

The only insurance hitherto generally available for the risks or hazards in crop production has been that of hail insurance, and even this form of coverage is of relatively recent origin. Hail insurance on growing crops has grown during the last decade into a business of some magnitude. The total premiums for 1919, which marks the highest point yet reached, exceeded \$30,000,000. More than half of these premiums were collected by joint-stock fire insurance companies, about 60 in number, which write hail insurance more or less as a side line. The remainder was divided almost equally between specialized hail insurance companies doing business on the mutual plan and State hail insurance funds or departments. The total risks covered amounted to about \$560,000,000. Almost one-half of these risks was carried by the joint-stock companies and the other half was divided equally between the mutuals and the State departments in North Dakota, South Dakota, Montana, and Nebraska.¹

A certain amount of fire insurance has also been written on standing grain in some States of the West. This form of insurance is most common in districts where large acreages of wheat are left standing until thoroughly ripe and dry and then cut and thrashed in a single process. The insurance takes effect on the grain in the field and as a rule follows it until it is sold or stored in a commercial elevator or warehouse.

In recent years attempts have been made to work out a more general plan of insurance coverage for farm crops. The first attempts of this kind were made in 1917, when three joint-stock fire insurance companies offered crop insurance in North Dakota, South Dakota, and Montana. Two of these companies wrote practically identical contracts and the contract of the third differed but little from the others. A brief outline of the leading features of the plan follows.

The insurance covered all the hazards to which crops are subject, with the exception of fire, floods, winterkill, and failure on the part of the farmer properly to till and care for his crops. The hail hazard was specifically included in the coverage offered by this form

¹ U. S. Dept. Agr. Bull. 912, "Hail Insurance on Growing Crops in the United States," p. 11.

of policy. The amount of insurance was fixed at the relatively low figure of \$7 an acre and the insurance applied to a specified field area, the crops on which might include any or all of the following grains—wheat, flax, rye, oats, barley, and spelt. In case of total failure of the crop on such area, the company agreed to pay the face value of the policy, or \$7 an acre. In the event of partial loss, the indemnity provided for was equal to the difference between the value of the crop harvested on the field area insured and the face of the policy, it being specifically stipulated that the entire area insured in a given policy should be considered a single risk. Furthermore, the partial crop was valued at prices stipulated in the policy, namely, wheat, \$1; flax, \$1.75; rye, 70 cents; and oats, barley, and spelt, 50 cents a bushel. The insurance, therefore, even though written in terms of money, covered yield rather than returns on a monetary basis. In other words, the insured was protected in a measure against crop damage, but not against a possible drop in the prices of the crop produced. Adjustment of all partial losses was necessarily postponed until after the insured crops had been thrashed.

These first attempts at general crop insurance proved rather disastrous for the companies that undertook them, owing, in part, to the severe drought that occurred in large sections of the States mentioned and, in part, to inadequate safeguards by the companies against the assumption of risks after severe damage had already taken place. The losses incurred under these contracts were to a considerable extent repudiated by the companies. Inability to settle in full was pled. In some cases fraud on the part of the insured was alleged and many claims were tentatively settled by the return of the premium collected. The outcome of this first attempt to provide a general crop coverage is much to be regretted.

For two years following these experiments of 1917, no general crop insurance, so far as the author is aware, was written in the United States. During the last two years, however, the plan of offering a crop insurance contract has been revived, at least two of the larger fire insurance companies having written such contracts.

One of these policies, which was written by one of the two companies quite extensively during 1920, in effect guarantees the farmer a specified income from each acre insured unless damage results from fire, hail, wind, tornado, failure of the seed to germinate, or failure on the part of the farmer properly to do his part in seeding, cultivating, or harvesting the crop. Losses or damage through the elements, including frost, winterkill, flood, and drought, and from insects or disease are specifically covered by the policy.

The amount of insurance to the acre written is based on the investment in the crop as determined by allowing a fixed amount for each process in preparing for, cultivating, and harvesting the crop

in question plus an allowance for seed and for rental value of the land. Unlike the contract described above, the policy does not place a fixed value on the grain harvested, but provides instead for valuation on the basis of market price at the time of adjustment. The company, therefore, in effect, gives protection against a drop in prices, as well as against crop damage. This feature of the policy caused the venture to prove a costly one to the company in 1920 because of the unexpectedly heavy drop in prices.

A crop policy even more recently devised involves a plan materially different from either of those already described. The coverage as to hazards insured against is, however, practically the same as in the contract just outlined. In neither of these policies is the hail hazard covered. Under the plan embodied in this policy, however, the amount of insurance to the acre that an applicant may receive is based on a certain percentage of his average yield during the past five years, such part of the average yield being translated into dollars by applying to it a value per bushel or other proper unit of measure based on the price prevailing during the period in question. Thus a farmer who on a given farm during the past five years has averaged 48 bushels of corn an acre may be offered insurance in an amount equal to the value of about 36 bushels at the average price for corn during the past five years. If such average price were found to be 50 cents a bushel the insurance might be placed at \$18 an acre.

One of the most important differences between this policy and either of those previously described is the plan provided for settlement of losses. In the case of total destruction of the insured crop the company agrees to pay 75 per cent of the cost of the field operations actually performed, such indemnity not to exceed 75 per cent of the total insurance carried. Furthermore, it is provided that the indemnity shall in no case exceed the cost of replacing all or any part of the quantitative returns on which the insurance is based with products of like kind and sound quality. Finally, it is provided that indemnity shall in no case exceed the amount, if any, by which the amount insured exceeds the market value of the crop harvested. Under this provision a change in price in either direction may be taken advantage of by the company.

PRINCIPLES OF CROP INSURANCE.

The need of the farmer is a form of insurance that (1) will safeguard him as far as practicable against all unavoidable losses which would seriously cripple him, and (2) can be obtained at a cost or premium which he can afford to pay.

This means, in the first place, that the protection must be limited to actual loss of a material part of the investment in a crop, reasonable compensation for the farmer's labor, and a fair rental of the land

being included in such investment. If it is attempted also to cover the loss of prospective profits by partial damage to a crop promising a yield above the average, the cost is sure to be prohibitive.

If insurance consisting of the collection of premiums and the distribution of such premiums to those incurring a loss under the insurance contract could be conducted without expense, it might be wise to insure against every conceivable source of loss, thereby practically equalizing and standardizing the income. It is, of course, no more possible to achieve this than it is for a locomotive to turn into tractive power all the energy contained in the coal that it consumes. A greater or less proportion of the amount contributed by the insured as premiums must be used to meet the expense of conducting the business, or, to carry out the figure, to overcome the frictional element of the insurance machine. It is, therefore, possible in the long run for an insurance company to pay back in indemnities to its members or patrons only a materially smaller amount than the sum collected from the insured in the form of premiums.

The important fact to be made clear may be further explained by pointing out that, covering a period of years, a farmer ordinarily secures a greater net income by carrying his own risk than will accrue to him if he purchases any form of crop insurance from year to year. This is true, however, only on condition that no loss suffered is sufficiently serious to cause him to lose his farm or to handicap him in his farming operations. It must be concluded, therefore, that insurance is to be recommended against such crop losses as would seriously cripple the farmer. On the other hand, it is a form of extravagance to insure against such losses as he can bear without undue inconvenience.

It may be laid down as another principle that the ideal crop insurance will, to the extent indicated, provide protection against all unavoidable hazards to which the crop is subject. If one of these hazards is left unprovided for in the insurance contract, the insured may lose his crop from that hazard and find himself worse off for having carried insurance by the amount of premium paid or premium obligation assumed.

In the final analysis, there is little more logic in carrying crop insurance against certain specified hazards with the insured carrying the total risk against other hazards than there would be in taking out a life insurance policy against certain specified diseases. The thing that the buyer of life insurance seeks is the positive assurance that in the case of his premature death the economic loss sustained by his dependents will to a greater or less extent be made good by the insurance. Similarly, the thing needed by the producer of crops is the assurance that if these crops fail to produce a reasonable harvest, no matter what the cause of such failure may be, assuming

that he himself has fully performed his part, he will be indemnified for the loss that he has sustained.

It is hardly necessary to point out that in no case should the insurance safeguard a man against his own negligence or carelessness. Any insurance which does this tends to create a form of moral hazard that no company can afford to assume and also to diminish the efficiency and productivity of agriculture as a source of national wealth.

While the crop insurance policy to meet requirements fully must cover all unavoidable hazards, it would no doubt be going to extremes to assert that, in the absence of an offer of such a policy on favorable terms, no insurance should be purchased. In certain parts of the country the hail hazard is relatively severe. The average loss for a State by reason of hail is rarely if ever as large or as widespread as the loss from certain other climatic hazards, but the loss to those who do suffer from it is often very severe. Not infrequently the crops of individual farmers are totally ruined. Because of this peculiarity of the hail hazard, losses therefrom being concentrated on a relatively few and the damage therefrom being readily distinguishable from that brought about by other causes, it is practicable from the point of view of the insurance organization to give protection against this hazard alone and to hold down its expenses to a reasonable percentage of the premiums. The protection offered by hail insurance may be well worth what it costs. Where so-called crop insurance covering a variety of hazards is offered, however, the hail hazard should certainly be included. It should not be necessary for the farmer to secure two insurance contracts in order to be protected against serious or total loss. Economy in insurance operations and convenience to the insured argue for complete coverage in a single policy.

It has already been pointed out that the farmer can not wisely shift to an insurance company the risks which he can carry himself without undue danger to his safety and prosperity. It may also be emphasized that the farmer can not afford to buy insurance protection against any of his risks if the expense item involved in the insurance operation is unduly large. The insurance machine must operate with reasonable efficiency if the seeker of insurance protection is to find it profitable for his needs. Assume, for instance, that 50 per cent or more of the premiums collected were absorbed in expense of operation, thereby making the total cost to all the insured equal or exceed the amount received by them in indemnities to cover losses incurred. It is obvious that it would be wiser for each one to take a chance on a serious loss and thereby have also a chance of retaining a liberal income in prosperous years. Under the conditions assumed, the purchaser of even a reasonable amount of protection would pay out in premiums a large part of his income in good years and possibly

more than his net income in leaner years. Such an arrangement would insure his ruin rather than his success.

This illustration, of course, applies particularly to forms of insurance covering hazards which are not subject to human control. Certain kinds of insurance, such as that against fire, loss of live stock by disease or accident, and, even more, certain forms of casualty insurance, involve the buying of a service in the nature of loss prevention as well as a guarantee of indemnity in case loss occurs in spite of preventive measures. In such cases, insurance might be profitable even when premiums collected are relatively large in proportion to the indemnities distributed by the company. In the case of crop insurance, however, the service of the company consists not in loss prevention but merely in the collection of funds and the distribution of these funds as indemnities to those who suffer loss. Under such circumstances the expense item must be only a minor part of the total cost to the insured if the purchase of protection is to prove a wise investment.

Three relatively distinct forms of crop-insurance policies based on the methods of determining the amount of insurance to the acre and the indemnity due when losses are incurred were outlined on pages 16 to 18. Under the first of these plans the insurance an acre is made an arbitrarily fixed and uniform sum for each acre insured. Under the second plan the maximum insurance an acre written is determined on the basis of actual investment in the crop by placing a specified value upon each operation in preparing the soil and tilling and harvesting the crop and adding to this sum a reasonable allowance for seed and rental value of the land. Under the third plan the average yield on the land in question during the past five years, coupled with the price of the product during the same period, is made the basis for determining the amount of insurance.

The first of these three methods of determining a proper amount of insurance to the acre has the advantage of extreme simplicity. Obviously, however, the unmodified plan could not be applied to a wide range of crops in different sections of the country without either greatly underinsuring some risks or overinsuring others. For general application some method of adjusting the insurance an acre to the investment involved, or the crop value, is essential.

The question may then be raised: Is the investment in the crop as determined by the number and cost of the field operations performed plus seed and rental, or the average income over a period of former years as determined by yield and price, the better basis for arriving at a safe and proper amount of insurance to be written?

As between these two methods, the first may be said to be the easier to apply in so far as the agent writing the insurance is concerned. The field operations already performed or to be performed

before the crop is ready for market are easily translated into terms of dollars by means of simple tables showing the cost of each operation; and the cost of seed and fertilizer, if any, as well as the commercial rental value, can no doubt be determined without much difficulty. The plan does not readily lend itself, however, to a differentiation between good farming and poor farming except as these factors are evidenced by the number of field operations performed. In other words, unless the agent takes great personal care, the farmer who plows, disks, etc., in a slipshod manner, uses inferior seed, and exercises poor judgment in other respects, is likely to receive the same amount of insurance as the farmer who performs all field operations in a first-class manner, uses the best varieties of seed, and exercises sound judgment with reference to the time of seeding, caring for, and harvesting his crops. Moreover, while the commercial rental supposedly reflects the productivity of the farm, rents are to a great extent the result of established custom and do not, as a rule, reflect with accuracy the productivity of a given farm.

The other method, that of average yield and price, has the disadvantage of being somewhat cumbersome and difficult to apply. Few farmers keep records of their yields from year to year, and without such records few will be able to give with any degree of accuracy the yield obtained for each of five years past. Furthermore, a very considerable percentage of the tenant farmers will not have tilled the farm they occupy for a sufficient number of years to give a reliable average yield. The plan has the merit, however, of measuring past results in so far as it is possible to secure the facts, and these form the most reliable basis for estimating the future results which are the subject of the proposed contract.

The determination of the amount of insurance an acre to be written is particularly important in the general plan of insurance here considered. In the ordinary insurance contract the amount of insurance placed on the various risks determines the size of the indemnity in case of loss, but does not, barring a moral hazard, affect the number of losses. Under the plan involved in each of the crop insurance contracts hitherto written, however, the insurance an acre determines not only the size of the indemnities that will occur, but also the number of cases in which indemnity will be due. To insure the corn fields in a given State or locality at \$24 an acre, or the equivalent in a stipulated yield, obviously involves not only twice, but many times, the risk involved in insuring the same fields at \$12 an acre. From the farmer's standpoint the chance of collecting all or a part of the second \$12 an acre would be several times the probability of collecting any part of the first \$12. The wise farmer, therefore, when he buys insurance under this plan, will buy as much an acre

as the company is willing to give him. To a large extent, the company for the same reason can give justice as between good and poor land as well as between good and poor farmers in a particular locality, merely by an adjustment of the amount an acre written, and without making any change in the rate of premium. This plan is not uniformly applicable, however, for the reason that climatic conditions make wide variations from the average yield much more frequent in some localities than in others.

The best method of determining the indemnity due in case of loss raises an equally difficult question and one quite as important as that of determining the amount of insurance that may be written. The first of the three forms of contract outlined provides that in case the yield an acre valued at the price stipulated in the policy does not equal the amount of insurance an acre, the company will indemnify the insured to the amount of such difference. Under this plan it is of no financial consequence to the company whether prices go up or down. The risk involved in price fluctuations, in so far as it affects income from yield obtained, rests entirely on the farmer. A simple illustration will make this point clear.

A farmer insures his wheat at \$7 an acre under this plan. The wheat is valued by agreement in the policy at \$1 a bushel. By reason of drought or other cause the yield is reduced to 5 bushels an acre. The indemnity due under these conditions is \$2 an acre, regardless of whether the local market price of wheat at harvest time is \$0.75 or \$1.50 a bushel. If the lower price prevails, however, the farmer will receive only \$3.75 for the 5 bushels harvested, while he will receive \$1 a bushel for each of the two bushels that he fell short of 7 bushels, the quantity in effect guaranteed him. His total income an acre will be \$5.75. If, on the other hand, wheat sells for \$1.50, the amount harvested will be worth \$7.50, equal, with the \$2 indemnity, to \$9.50 an acre. To the company, however, it makes no direct difference whether prices advance or fall except as the collection of premiums not fully paid in advance may be affected.

In the case of the second form of policy outlined, this situation becomes essentially reversed. Assume that a farmer insures his wheat at \$12 an acre under this plan, which, as against the hazards covered, guarantees him a yield that at market price will equal the amount of insurance. In case of total destruction of his crop he will be paid for such operations and such investment as have been already made in connection with the destroyed crop. Suppose, however, that by reason of one or more of the hazards insured against, the yield is reduced to 8 bushels. If the wheat at harvest time sells for \$1.50 or more, no indemnity will be due, since the amount harvested will bring a return equal to or greater than the sum stipu-

lated in the contract. But suppose, on the other hand, that wheat falls to \$0.80. The 8 bushels harvested will then be worth only \$6.40 and the indemnity due will be \$5.60 an acre. On the basis of this price, even a 12-bushel yield will call for an indemnity, assuming that damage has occurred from hazards covered by the contract, equal to the difference between \$12 and \$9.60, or \$2.40 an acre. To the farmer suffering crop damage from causes covered by the contract in such degree that his actual yield at market price falls below the insurance an acre, it makes no difference under this plan whether the price is higher or lower. To the company, on the other hand, high prices mean few and small losses, while low prices mean numerous and relatively large losses.

Turning now to the third and last form of contract previously outlined, conditions based on fluctuations in price take on still another aspect. Under this plan the company in effect reserves to itself the right to make settlement in kind on the basis of the average yield used in determining the insurance an acre, at the same time retaining the option of settling the claim on a basis of dollars an acre with the crop valued at market price.

Assume again that a farmer carries insurance of \$12 an acre on his wheat, this figure in this instance having been determined by taking three-fourths of a 16-bushel average yield and an average price of \$1 a bushel. Owing to one or more of the hazards insured against, the yield, as in the preceding illustration, is only 8 bushels an acre. Assume first that wheat following harvest is worth \$1.50 a bushel. The company, of course, invokes the clause in its contract providing that its liability shall in no case exceed the amount, if any, by which the amount insured exceeds the market value of the crop harvested. Since the value of the 8 bushels harvested is \$12, no indemnity is due. But suppose, on the other hand, that the price following harvest is only \$0.80 a bushel. The company then relies on the provision that in no event shall its liability under the contract exceed the cost at the time of harvest to replace all or any part of the estimated yield with products of like kind and sound quality. The company, therefore, tenders the insured the equivalent of 4 bushels at \$0.80, or \$3.20. This sum, together with the 8 bushels harvested, also at \$0.80, makes the gross returns to the insured \$9.60 an acre.

Had wheat remained at \$1 a bushel the indemnity would, of course, have been \$4 an acre, but with a market price at harvest time standing at \$1.50 the company pays nothing, and with a market price of \$0.80 it pays only \$3.20. As in the case of the preceding plan of contract here considered, the company has fewer losses by reason of the rise while such losses as occur are reduced in amount.

In the case of this last form of contract, however, the company benefits from a fall in price, as well as from a rise, while the insured who suffers damage has his indemnity reduced in proportion as the market price is lower than the price on the basis of which the amount of insurance was determined.

It should perhaps be pointed out in this connection that such changes in price as have been witnessed in the last few years are decidedly abnormal and that under relatively stable price conditions the third form of contract would be practically as advantageous as either of the other two. There is serious danger, however, that the applicant for insurance will not read his contract and will not have his attention called by the agent to the plan of settlement, so that when changes in price occur he will be expecting in case of loss an indemnity sufficient to make his income equal to the insurance on an acre specified in dollars on the face of the policy.

A company writing a more liberal policy from the point of view of the insured must charge materially higher rates of premium than are required to carry out a contract with less favorable terms of settlement. Given a sufficient difference in premium, the third contract here considered might represent a better investment than either of the other two. A plan under which the company profits by a fall in price as well as by an advance, however, is not likely to inspire confidence and good will among the insured, even if allowance is made for this advantage to the company in the premiums charged.

Dropping this third plan of loss adjustment from further consideration, the question still remains: Should the company writing crop insurance assume a material part of the risk involved in a drop in prices as well as that of crop failure, or should in effect yield only and not income be insured? Much can be said in favor of either of these two plans.

The first plan is more simple to administer, since, the value of the crop being agreed upon in the contract, there can be no haggling over which one of continuously changing market prices shall be used in the settlement. Furthermore, the farmer and not the company determines what crop shall be planted and insured. The adjustment of supply to market demand is, therefore, in the hands of the farmer, and it may be argued with much plausibility that where the control is there must responsibility also lie. The weakest point in the plan is perhaps the fact that when the market price falls below the price stipulated in the contract it becomes actually profitable for the farmer to have a damaged crop still further reduced in yield, since for the differences between the actual yield and the guaranteed yield he is compensated on a basis of a price higher than the one he receives for his actual yield.

In favor of the second plan, which guarantees income rather than yield, it may be said that the affairs of the farmer are adjusted on the basis of an expected income. Furthermore, the guaranteed income is presumably limited to such an extent that the farmer will invariably hope and expect to exceed it. He will, therefore, exercise the same judgment in the adjustment of his various crops to prospective demand as though he bore the entire responsibility for financial results. Objection to this plan is likely to come from the company rather than from the insured.

SUMMARY.

The ultimate form of crop insurance contract in all probability still remains to be devised. The writer ventures, however, by way of summary to emphasize the following principles as fundamental to a sound plan for crop insurance:

1. The insurance must cover only such crop damage as will result in serious financial loss to the farmer. This means that only a reasonable amount of insurance an acre must be written. For establishing such reasonable amount the average yield and price for a series of past years is perhaps the best basis. It means, furthermore, that the acreage of a given crop, if not the entire farm, must be insured as a unit and adjustment made on the basis of average yield of such acreage. The total loss of crop on one or a few acres out of a hundred is not a serious loss if the acreage as a whole gives average returns or a substantial part of such average.

2. The insurance must cover any and all hazards which are beyond the farmer's control. Insurance which protects against certain hazards and leaves the insured exposed to total loss from other hazards beyond his control is not real crop insurance.

3. In no case must the insurance protect against loss from carelessness or negligence on the part of the insured. Such protection would involve a moral hazard, the encouragement of which is against the best interest not only of the company but also of the insured and of public welfare in general.

4. The premium, or cost of insurance, must bear a reasonable relationship to the value of the protection that it purchases. This means that the expense item in the expenditures of the insurance organization must be held to a minor part of the premiums collected; that profits, if the organization operates for profit, must be moderate; and that the bulk of the premiums must be available for the payment of current losses and in favorable years for additions to a reserve for the payment of future losses.

5. The method of adjusting loss must be such that the insured will receive indemnity for crop damage in the amount or on the basis that

he is led to expect from the figures indicating the amount of insurance an acre. The company should not profit by a calamity to the farmer in the form of reduced prices for his product.

6. An early adjustment should be provided for in case of total failure of an insured crop, or such an approximation to failure that it would not pay to mature and harvest the crop. The part of the income or yield guaranteed by the contract, which becomes due under such circumstances, should be plainly stated and should not exceed the value of the labor and other costs, including rental, that are actually lost to the insured in connection with the crop.

7. All adjustments involving only partial damage should, so far as possible, be left until after the crop has been harvested and put into marketable form so that quantity and grade can be determined. This makes possible economy in adjustment expense.

8. Lastly, there must be a certain degree of understanding between the farmers and the company or agency offering the insurance if protection is to be available on truly favorable terms. Crop insurance must be bought on the same principle as fire insurance is purchased, merely as a guaranty against serious loss and not with the expectation of securing an indemnity every two or three years. If the insurance is to be written with the idea that frequent indemnities for minor cases of crop damage are to be paid, it necessarily becomes so expensive that those in greatest need of it can ill afford to buy it. The insured should find some method of helping the organization providing protection to reduce the heavy expense connected with the acquisition of business which now prevails in nearly all lines of insurance, at any rate where the business is conducted on a commercial basis. In some of the European countries, farmers' organizations have applied the principle of collective purchasing to their insurance problems. Perhaps the farmers' organizations of the United States will find some way of solving this problem on a plan consistent with American laws and American conditions.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY



UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1044



Contribution from the Bureau of Markets and Crop Estimates
H. C. TAYLOR, Chief

Washington, D. C.

April 19, 1922

SELF-SERVICE IN THE RETAILING OF FOOD PRODUCTS.

By F. E. CHAFFEE, *formerly Investigator in City Marketing*, and McFALL KERBEY, *Assistant, Bureau of Markets*.

CONTENTS.

	Page.		Page.
Introduction.....	1	Problems in self-service.....	14
Self-service.....	2	Handling perishable farm products..	35
Advantages and disadvantages of self-service.....	4	Accounting.....	49
		Summary of investigations.....	39

INTRODUCTION.

The cost of distribution plays an important part in the final cost of food to the consumer. Under the methods that have been in common use for generations in the United States this cost is now very high. It has been estimated¹ that of the price paid by the consumer for perishable farm products used for food, from 25 to 75 per cent commonly goes to pay the cost of distribution—that is, the cost and profits of handling after the products leave the hands of the producer. In the case of certain products and certain distributing agencies the proportion of the final price which goes to pay distribution costs is even greater than 75 per cent.

Of the cost of distributing food products, the cost of the final step, retailing, is of major importance, since that single step, on the average, approximates the cost of all the preceding distribution steps together. There are many good reasons for this, but we are led to the conclusion that one of the most urgent points at which to attack the high cost of living is through the group of agencies concerned with the retailing of foods.

Several recent developments in the distribution field have had a tendency to reduce the cost of retailing. Such developments are par-

¹ Weld, L. H. D., *Studies in Marketing of Farm Products*, p. 7.

ticularly important to farmers, since much farm produce is highly perishable and necessarily must have a rapid turnover if waste is to be avoided. The retailer is the final outlet, and if he must charge a high price for his goods, because of his heavy operating expense, he blocks the channels of trade and causes a slowing down in the flow along the entire distribution system, all the way back to the producer. Therefore, any method that will reduce the cost of retail-store operation, or make the retailer more efficient, is of importance to the grower of perishable farm products as well as to the consumer. It will increase the grower's outlet because of the reduced cost of the produce to the consumer.

Since a large percentage of the farm products distributed are sold through grocery stores, it has been considered advisable to study the methods, cost of operation, and possibilities of some of the new types of such stores in order to determine whether there is a probability that costs of retail distribution of foodstuffs, including farm products, can be materially lowered in the immediate future.

During most of the period between 1900 and 1910 there was an increasing demand for service. Competition forced dealers to add one service after another until the system became overburdened. With the marked increases in prices after the outbreak of the World War there came a reaction. Consumers had to give more thought to the buying of foodstuffs, and prices, rather than convenience and service, became the all-important consideration. An increasingly large part of the public came to realize that under the more common methods of retailing, the cost of service, though advertised as free, was necessarily included in the price of merchandise, whether or not the customer availed himself of such service.

As a result of this growing recognition that a cost is necessarily attached to service, several types of so-called nonservice grocery stores have come into existence. Of these the self-service store has been the most radical development, since it has come closest to the complete elimination of service. This type of store is generally believed to have originated on the Pacific coast, but its development probably was simultaneous in several parts of the country.

In this bulletin the "service" stores referred to are of the "cash and carry" type. They are used in comparison with "self-service," because they approach the latter most nearly in cost of operation and service rendered to customers. If comparison were made with the "credit and delivery" type of store, the differences would be much greater.

SELF-SERVICE.

Self-service means, of course, to serve one's self. The use of the phrase in connection with the retail distribution of merchandise applies to those retail establishments so constructed and operated

that customers are required to make their own selections of merchandise, taking the goods off the shelves or tables and carrying them to a special place where payment is made for those selected. This system applies not only to the distribution of foodstuffs, but is applicable to almost any line of merchandise. It is being successfully applied to the retail distribution of clothing, millinery, shoes, dry goods, and other lines, which at first thought would seem to be of such a nature as to prohibit their sale under the self-service plan.

There is a common belief among the retail grocers of the country and the general public, especially in the East, that the term self-service is used only in connection with a certain corporation operating a number of self-service stores. This is no more true than that the expression "chain-store method of distribution" means a certain company operating a chain of stores. Neither is the idea correct that permission must be secured from any corporation to operate a self-service store. The corporation referred to does hold certain patents covering floor plans and certain interior arrangement of their stores, but principles of self-service can not be patented, being nearly as old as distribution itself. Particular floor plans and arrangements apparently are not vital to the operation of a self-service store.

In the ordinary type of retail store merchandise can not be purchased without paying for the cost of certain services. There is no such thing as "free service," as commonly advertised by many retailers. A direct charge for service may not be made, but its cost is included necessarily in the selling price of the merchandise. The average food store has only one price for each article sold. One person may buy an article, pay cash, and carry it home. The next purchaser may ask to have a similar article delivered several miles away and to have it charged, not paying for it for 30 to 60 days. Yet to each of those customers the price is the same. This is obviously unfair to the "cash and carry" customer. Furthermore, such a system stimulates a demand for service and penalizes the consumer who does not ask for it nor want it. In the average retail store the cost of delivery amounts to about 2.4 per cent of total sales and the cost of credit to about 1 per cent² (one-half per cent loss from bad debts and one-half per cent for keeping the account). If a charge were made for the credit and delivery service rendered, based on the actual cost of the service, the second customer would pay about $3\frac{1}{2}$ per cent more for his goods than the first.

Self-service may be operated on the "credit and delivery" basis, but in this bulletin it is assumed to be operated on the "cash and carry" basis. In fact, it is operated on the "cash and carry" basis in nearly every instance. In a few cases delivery service is furnished

² Figures compiled by the bureau of business research of the graduate school of business administration of Harvard University.

if desired, but a specific charge is made, and usually the actual delivery is performed by an outside agency.

ADVANTAGES AND DISADVANTAGES OF SELF-SERVICE.

The advantages and disadvantages of self-service are marked, so much so, in fact, that it seems apparent that the principle of self-service can not be applied in a haphazard way to any store at any location or under any management and be entirely successful. But under proper conditions, which will be explained later, it has proved to be a factor in making possible a considerable reduction in the cost of distributing merchandise to the consumer. In order that the advantages may be utilized to the fullest extent, a considerable amount of study previous to installation is necessary, and in order that the disadvantages do not offset the advantages an efficient management is essential.

Any store to be entirely successful must necessarily have a good location and an efficient management. But the self-service plan involves new features and problems to which particular attention must be paid. If operated along the lines of the ordinary grocery store without previous study of its special problems the chances for its success are limited. These special problems are not in themselves difficult, but demand only full understanding before the principles are put into operation.

ADVANTAGES.

LOW OPERATING EXPENSE.

Low operating expense is the greatest advantage and the feature which gives self-service its claim to a prominent place in the system of distribution. If it were not for this feature, self-service would be unknown, since the fact that it involves a decrease in service on the part of the distributor can hardly be considered an advantage in itself. The eliminated service must necessarily be compensated for by a reduced cost of merchandise to the consumer, all other things being equal, in order that the consumer's trade may be obtained and held. This is made possible by the reduced cost of doing business.

There is a direct reduction in the wage expense because of the small number of employees necessary to operate a self-service store. As compared with the service store, whether "cash-and-carry" or "credit and delivery," this expense usually is practically cut in half. In stores having a very large volume of sales the saving, under efficient management and arrangement, may be even more than this. In general, the larger the volume the greater the economy that can be effected. These economies do not result entirely through greater efficiency (which may be applied to any business), but are partially inherent in the principle itself.

Under the service plan an added volume of business necessitates more clerks to wait on the additional customers. This is not necessary under the self-service plan. An increase in volume necessitates only additional stockmen and cashiers, which, of course, are necessary in a store of any magnitude under any plan. For example, let it be assumed that there are two stores doing a business of \$500 a day, one operating under the self-service plan and one under the cash-and-carry plan with salesmen. Studies of stores of both types indicate that under the former plan it would require, at the outside, about two stockmen, one cashier, and one checker, while under the latter it would probably require five clerks to wait on the customers, one stockman, and one cashier. This includes only those employees who handle the merchandise or come in contact with the customers. The saving in number of employees by self-service would be 43 per cent. Now, let it be assumed that these stores are doing a business of \$1,000 a day. A survey of grocery establishments of both types indicates that the \$1,000 a day self-service would probably require two cashiers, two checkers, and three stockmen, while under cash and carry ten clerks, two cashiers, and two stockmen would be needed. This would be a saving of 50 per cent in the number of employees under self-service. Obviously, stores of the two types doing exactly the same amount of business and operating under conditions exactly comparable in every respect can not be found; but the studies of existing stores under closely comparable conditions indicate the correctness of these deductions.

If the saving is translated to money value, it is even more apparent because of the different rates of wages paid for different classes of work. If a good sales clerk is paid \$25 per week, a stockman or checker \$20 per week, and a cashier \$15, which fairly represents the difference in wages paid these classes, the weekly wage expense, with the store doing \$500 per day, would be \$75 under self-service and \$160 under cash and carry, or a saving of 53 per cent by self-service. If the stores were doing a business of \$1,000 a day, the wage cost under self-service would be \$130 and under cash and carry \$320, or a saving of 68 per cent in favor of self-service.

The average expense for wages of salesmen in the cash-and-carry store referred to, doing a business of \$6,000 a week, would be, therefore, between 5 and 6 per cent of the total sales. The self-service store with a like volume of business and the weekly wages referred to would operate on a wage expense of between 2 and 3 per cent of total sales.

There are other savings in expense under the self-service plan which, although not so marked as those of wages, are of considerable importance in the aggregate. These are largely attributable to the

greater volume evidently possible under self-service than under the cash-and-carry plan, even though both utilize the same floor space.

Such "fixed charges," as for rent, heat, light, insurance, depreciation, and perhaps telephone, would remain the same, no matter how much business was done in any particular store. If a certain store under the cash-and-carry plan, with only space enough to do a \$500 business, changed to self-service, studies show that it could probably handle a \$1,000 business. All fixed charges when measured as percentages of total sales would in such a case be reduced one-half. The fixed charges in cash-and-carry stores amount on an average to about 2 per cent of sales. If the change were made with the result assumed above, the fixed charges would be reduced to about 1 per cent of sales. Such expenses as advertising, management, buying, and miscellaneous expense would be slightly higher in doing a \$1,000 business instead of a \$500 business, but they would not be twice as much. It would require a doubling of the actual expense mentioned in order that its percentage of the sales remain the same. Since such expense would be increased only slightly when sales were doubled, the percentage of sales would therefore probably be between 1.5 per cent and 2 per cent, as against 3 per cent for the \$500 cash-and-carry business. The wrapping expense in terms of percentage would remain about the same, as it is directly proportional to the amount of merchandise sold.

Up to this point, under the conditions assumed, a saving of about 5 per cent in expense would be effected. The figures used have been more or less arbitrary, but are representative enough for this demonstration. In a later chapter more exact figures as to self-service operation will be given. In some instances stores operating under the plan have effected a saving of around 10 per cent of sales over the average expense necessary for the operation of a cash-and-carry store. This has resulted from efficient management and the taking of full advantage of those economies inherent in the self-service plan.

SMALL INVESTMENT.

As previously stated, the principle of operating on a small margin of profit, rapid turnover, and large volume should go hand in hand with self-service.

As perhaps twice the amount of business can be done under self-service with practically the same capital investment and floor space, the same percentage of net profit on sales is not necessary under this plan as compared with the cash-and-carry or credit-and-delivery plans in order to return to the operator a reasonable profit on his investment.

So many factors, such as location, type of trade, trend of business conditions, enter into the volume of trade of a given store that

definite proof can not be obtained as to the increased amount of business which can be done with the same floor space, but all of the studies made of properly managed stores tended to support the statement as given above.

Suppose a grocer doing a \$500 business per day under the cash-and-carry plan changed to the self-service plan and, because of the trade-drawing power of his reduced prices, made possible from a lower operating expense, was able to do a business of \$1,000 per day. Also suppose that under the first plan his prices were based on a 5 per cent margin of net profit, which he considered would bring him a fair return on his capital invested and his business ability. Under self-service under the conditions assumed he could base his prices on a 3 per cent margin of net profit and still make more money than before. In this way he would be increasing his own return while giving the consumer an additional 2 per cent reduction in the cost of the merchandise purchased.

PARTIAL SOLUTION OF HELP PROBLEM.

One of the most important and difficult problems with which the average business man has to deal is that of help. This is especially true of those who have to employ sales persons, since their personality and appearance, as well as their technical ability, must be carefully considered. The sales person is the direct representative of the business, and a great deal depends on him. Next to the merchandise carried and its selling price, the sales person is chiefly responsible for the attitude of the customer toward the business. It is his attitude toward the purchaser, to a large extent, that gains or loses the customer trade. If one asks the average housewife why she does not now trade with a certain store, she is as likely to say that she did not like the clerk as she is to say that the prices or merchandise were not right.

To make sure that the sales people will properly represent the employer requires considerable time and expense in training and the payment of high wages. Under the self-service plan this problem is largely eliminated. It is still present to a certain extent, but it is much less complicated, as the employees can be chosen mainly with one requirement in mind—their mechanical ability, for the customer does not come in contact with the employees, except at the cashier's desk.

CUSTOMERS' SATISFACTION.

Possibly one of the most annoying conditions that has arisen in connection with the development of cash-and-carry stores is the inability to take care of the customers during the rush hours. The system is rather inelastic in that respect. In order to handle the customers properly during the busiest hours, a larger number of clerks

is necessary than can be efficiently employed through the remainder of the day.

Some of the chain-store companies have given up trying to supply adequate service to the customers during rush periods because it was found to be too expensive. As a result, the customers lose much time, grow impatient, and are harder to please. The overworked clerks are likely to hurry the customers in their selection of goods and to become discourteous at times. Numerous customers endeavor to aid the situation by selecting as many of their purchases as the store arrangements will permit and bringing them to the counter, so they may be waited upon more quickly. This partial self-service is rather unsatisfactory from both the dealers' and customers' standpoints. As only a few packages are wrapped in cash-and-carry stores, the clerk does not know certainly whether the customer has paid for the articles he has in his hand or not. The customers perform this work with a certain amount of mental protest, not knowing whether they will be criticized by the clerk for adding to the general confusion.

One of the most satisfying features of the self-service plan is the ability to take care of the customers during the rush hours with a minimum of inconvenience to the dealer and the customer. It requires only from one to two persons (depending upon the system of checking used) to double the capacity under the self-service plan, and these can be drawn from work which is not usually pressing at that time. This elasticity of the self-service plan is a very economical feature. It eliminates, to a large extent, the extra-help problem, which is a rather difficult and unsatisfactory one to both the employer and the customers. Persons working odd hours are usually more or less inexperienced and unreliable, and generally present more of a management problem than does the regular help.

A psychological advantage is also derived from this elasticity. The average person is so constituted that time spent in action, either mental or physical, is more satisfying than the same amount of time spent in inaction and waiting. Suppose that during a busy period of the day a customer has to spend 15 minutes in making a purchase of groceries, and that the same amount of time would be required whether the goods were bought at a self-service store or at a service store. Assume that in the service store the customer spends 10 minutes waiting for a clerk, 5 minutes making purchases, and 2 minutes waiting at the checker's counter, and that in the self-service store 13 minutes are used in making purchases and 2 minutes in waiting at the checker's. While the customer may spend the same amount of time in each place, it is evident that he would emerge from the self-service store in a much better frame of mind, simply because he has had to wait unemployed only one-fifth of the time in that store that he did in the service store.

Under actual conditions, the time spent in the self-service store is considerably less on the average than in the service store; therefore there is a physical as well as a psychological advantage. A customer familiar with the self-service plan can wait upon himself in approximately the same amount of time that it takes a clerk to wait on him in the service store. The extra time involved in ascertaining the location of certain articles in the one is usually offset by the time consumed in conversation in the other. Therefore, using the above figures, the customer could make the purchases in the self-service store in about 7 minutes, as compared with 15 minutes in the service store. Such a saving in time, of course, would be effected only during the rush hours, but since the majority of people buy during those hours the total time saved would be large.

During the quieter part of the day a customer can be waited upon as soon as he comes into the service store. With either plan the same amount of time will be involved in making the purchases. Therefore if any advantage exists in self-service under these conditions, aside from lower prices, it will be found probably in the general attitude of the customer toward the plan. Does such an advantage exist? The experience of numerous operators indicates that it does. Whether or not this is merely because of the novelty is a debatable question. There seem, however, to be certain psychological forces involved which have a tendency to throw the advantage toward the self-service plan. Groceries have heretofore been convenience goods; that is, they were purchased at the most convenient place with not much regard to price. But of late they have tended to enter more and more into the shopping class; that is, they are now being bought after a closer comparison of quality and price.

The fact that the accessibility of the merchandise appeals to most women is recognized by many of the large department stores and by the 10-cent chain-store organizations. A woman likes to be free to take time in the examination and selection of her purchases. She seldom feels perfectly at ease in doing this when attended by a sales person. Under self-service this disadvantage is done away with. A purchaser coming into the store has free access to every article for sale. She is her own saleswoman, and in making careful examination of the merchandise she is using no time but her own, and therefore is entirely at ease. If she wishes to ask any questions about the goods, there is some one on the floor to answer them, but he is merely an information aid and not a salesman. This advantage is more marked in the selling of larger articles (clothing, furniture, etc.), where the cost per article is greater; but it is evident in the sale of groceries.

Another psychological appeal in self-service which can not be overlooked is the natural satisfaction which most people derive from getting behind the counter. The average person generally wishes to handle the goods on a grocer's shelves and enjoys the opportunity to do so.

EDUCATION THROUGH DISPLAY.

The usual procedure followed by the customer in purchasing groceries is to make out a list of the articles desired, go to the grocery store, and give the clerk the list. The clerk gets the articles, wraps them up, and takes the money. The customer may ask several questions as to the quality or price of a few articles (usually fruits or vegetables), and the clerk may suggest one or two other articles to the customer. Aside from this, the customer has merely had his order filled. He sees only a small part of the stock on sale, usually not more than those articles on special display. He has been in the habit of relying entirely on the sales clerk and does not take advantage of the opportunity to examine the goods in order that he may know what the dealer carries in stock. In fact, most of the stock is on the shelves behind counters, which prohibits a close inspection.

Under self-service the customer is forced to rely entirely upon himself. In filling his list he comes in contact with nearly the entire stock. Consequently he comes to know the articles carried, and is reminded of goods he may have forgotten or has not thought of for some time. This does not necessarily imply that over a period of time he buys more groceries, but that he is less likely to have to come so often, and also that he is less likely to get into a rut in his buying.

DISADVANTAGES.

LIMITATIONS OF SELF-SERVICE.

There is probably no one method of distribution which from some angle does not fall short in supplying fully and to the best possible advantage all the demands that are made by customers. Self-service is no exception. It can not reach nor satisfy all classes of people, nor is it intended to do so.

There is, and doubtless always will be, a large group, perhaps even a majority, who will demand service of some kind. It may be only the service supplied by the clerks in cash-and-carry stores, or it may be delivery or credit. All service costs the consumer something, whether the cost is included in the price of the merchandise or whether it is an additional charge. There will always be people who are willing to pay for service, whether they need it or not, and also people to whom such service is a necessity. This must be fully understood and appreciated, as self-service should not be considered a panacea, but merely a method by which a certain class of people may be sup-

plied in a way which best satisfies their particular needs. That such a class exists and that it is of sufficient magnitude to justify amply the existence of this method has been fairly well demonstrated by the success of those now operating self-service stores.

LACK OF SALESMANSHIP.

Both consumers and dealers have expressed an objection to self-service, as they feel that a salesman is an essential connecting link between the buyer and the merchandise and that the elimination of the salesman causes much confusion on the dealer's as well as the customer's part. They feel that the consumer has no way of ascertaining the quality or grade of any particular article with which he was not familiar, especially with canned goods; that the dealer is limited largely to nationally advertised goods and is unable to call the attention of the customer to new products or special bargains. These objections are usually made by persons who have only a slight knowledge of the results of operating under self-service. While the objections are true to a certain extent, nevertheless, when compared with the advantages derived from this same lack of salesmanship, they seem to lose a large part of their significance. Also, these disadvantages can be partially eliminated through proper coordination of advertising methods and the backing up of the advertising by the display of merchandise. This problem will be dealt with in a later section.

Under the self-serve plan customers are forced to rely upon themselves in locating their purchases. While they have the opportunity to obtain any information desired, it is surprising in actual practice what few inquiries are made. This would seem to show that customers have a considerable knowledge of grades and brands which they do not use under the service plan.

INCONVENIENCE TO CUSTOMER.

Some purchasers object to self-serve stores because they sometimes make it necessary for the purchasers themselves to handle vegetables to which earth adheres or articles that may be dusty. They also sometimes object to buying such commodities as bananas by the pound. Such customers obviously should go to the stores that are better fitted to give them the kind of service they require and they should be willing to pay the higher prices for the goods so received.

THIEVERY.

The question of thievery in connection with self-service has probably had more widespread publicity than any other feature. It is a question on which strong opposing views are held. Some operators say that the loss through thievery is less in the self-serve store than

in a service store, others that it is no more in the former than in the latter, and some dealers believe that it exists in self-service to such an extent as to make the plan entirely impracticable. It is almost impossible to determine the exact percentage of loss from this cause in any store. Therefore the views held are practically the result of supposition and incomplete observation.

"Don't you lose a great deal of merchandise under this plan?" is the first question usually put to operators of self-serve stores. Under all other methods of distribution the potential customers have become so accustomed to having restrictions imposed upon them as to their movements while in any store that they do not seem to be able to grasp the feasibility of allowing free access to all merchandise. Assuming that one of the impressions of the average customer in first coming into a self-service store is the ease with which small articles could be taken from the store without detection, since by far the greater majority of people are honest in practice, no action would result from it. This leaves only a small percentage who might be influenced by the thought. Is it not fair to assume that a large proportion of these would not put their impulses into action because of their fear of detection in passing the cashier? Simultaneously with the thought of stealing comes the fear of detection, and this fear would overcome the impulse to steal in a majority of cases.

This leaves a very small percentage who might actually put their impulses into action, but the percentage is large enough to receive considerable attention. The composition of this small group, the extent to which they pilfer, and the nature of their pilfering are matters about which little is known. From the experience of numerous operators, it seems that the persons who attempt to pilfer are by no means confined to the poorer classes and that the articles taken are not those which would be classed as necessities. The articles taken are necessarily usually small and more or less high priced, such as fancy sardines, anchovy paste, potted chicken, and small bottles of olive oil.

The actual extent of losses specifically from petty thievery has been variously estimated from almost nothing to 4 or 5 per cent of the total sales. A more common estimate is around 1 per cent. Through a system of retail stock control, which will be taken up in detail later, it is possible to determine rather accurately the shrinkage in the merchandise from all causes. This shrinkage is the difference between the value at selling price of the stock placed on sale and the money which is taken in, and is the result of various causes, including loss through overweight, evaporation, spoilage, deterioration, errors made by the cashier or clerk, and petty thievery, both on the part of employees and customers. It is impossible to segregate

all of these losses in order to determine to just what extent each occurs. In one of the self-serve stores investigated, which was operated under a retail stock-control plan, a number of these factors were eliminated, which would result in a more accurate determination of the loss through thievery. Practically all commodities were handled in packages put up in another department, to which was charged the loss resulting through waste and overweight. Few articles that would lose weight through evaporation were carried, and those were sold in packages, so that there was no loss to the store. Thus the shrinkage consisted only of cashier's errors and loss through thievery. As cashier's errors are as likely to be in favor of the store as against it, the shrinkage almost entirely represented thievery. It was slightly more than 1.5 per cent of the total sales.

Petty thievery exists more or less in all stores. While it may be slightly emphasized in self-service stores owing to the psychological effect of the store arrangement and the method of selling, it is not peculiar to this type. This is demonstrated very clearly by the experience of several large department stores that operate self-serve grocery departments while the remaining departments are operated on the regular-service plan. A large percentage of the persons caught stealing in the grocery department was found to have on their persons articles stolen from other departments and other stores.

The fact that the problem of thievery is especially brought to the attention of the self-serve operator and that special consideration is given to it goes a long way toward reducing the amount of stealing in such stores. On the whole, it seems doubtful whether self-serve stores lose more through thievery, relatively speaking, than other types of retail establishments, for the latter suffer not only from stealing on the part of customers but in some cases also from lax or even dishonest clerks. Methods of combating petty thievery are discussed later.

From one point of view the necessity for the exercise of great care in buying merchandise for self-serve stores of such quality that its worth can be recognized without the aid of explanations from salesmen may be looked upon as a disadvantage. Similarly, the necessity for the more careful grading of articles in self-service stores than in other stores may be considered disadvantageous. Keeping in mind, however, that most of the customers of self-service establishments are those willing to forego the multiplicity of grades as well as the service of fancy stores, it will be readily understood that the simpler stocks, involving smaller capital tied up, resulting from strict grading, compensate for the greater attention which must be given to buying and grading. The problems of buying and grading for self-service stores are discussed later.

PROBLEMS IN SELF-SERVICE.

As previously stated, the operation of a self-serve store involves numerous problems which are peculiar to this plan and which require careful consideration and a thorough understanding in order that self-service may be a success. In numerous cases grocers have changed their stores to self-service, failed to make a success, and sooner or later reverted to their old way of doing business. The main reason for their failure was that they did not recognize and put into operation the fundamental principles of self-service. They merely changed the physical arrangement in their stores to comply with self-service. As a result, practically none of the real advantages were obtained, while the disadvantages were magnified, and almost no attempt was made to cope with them.

LOCATION.

The self-service principle can not be counted upon to meet the needs of a very large percentage of people in any particular group, because of the limited service given. Therefore it is not a neighborhood proposition, but one that should be operated at a trading center. This does not imply that its usefulness is limited to the congested districts of large cities but that its location should be such that a relatively small percentage of the people in the locality, either transient or resident, will form a group sufficiently large to insure its success. The so-called corner grocery, because of the extensive and convenient service that it offers, appeals to a larger percentage of the people as a rule, in spite of the higher prices which it must charge. Therefore it does not require such a large territory from which to draw its trade.

The more specialized any system becomes the fewer it will reach in any given locality. The restricted application of self-service is not an undesirable feature, but rather a good one, provided this fact is fully recognized before the location of the store is determined. Its limitations make it possible to meet more fully the needs of that particular class for which it is intended.

It is possible that a self-serve store might exist as a neighborhood enterprise, but its success probably would be very limited, since the economies resulting under such conditions would hardly be sufficient to warrant its existence. In other words, in order that full advantage may be taken of all of the possibilities of self-service, a maximum volume of trade must be obtained. In order to obtain such a volume, the location of the store should be such that its patrons will be drawn from a considerable territory rather than from a radius of a block or two, as is often the case with the smaller grocery stores of the "corner" type.

STORE ARRANGEMENT.

The store arrangement and layout under self-service need not necessarily be in accordance with any hard-and-fast plans, in so far as details are concerned. In fact, there are nearly as many plans for the arrangement of fixtures and the display of stock as there are stores. For successful operation, however, one general requirement as to arrangement must be met; a separate entrance and exit must be provided for the section devoted to the display of goods for sale. In almost no case are the details of arrangement vital to successful operation, but there are certain problems involved which warrant careful consideration.

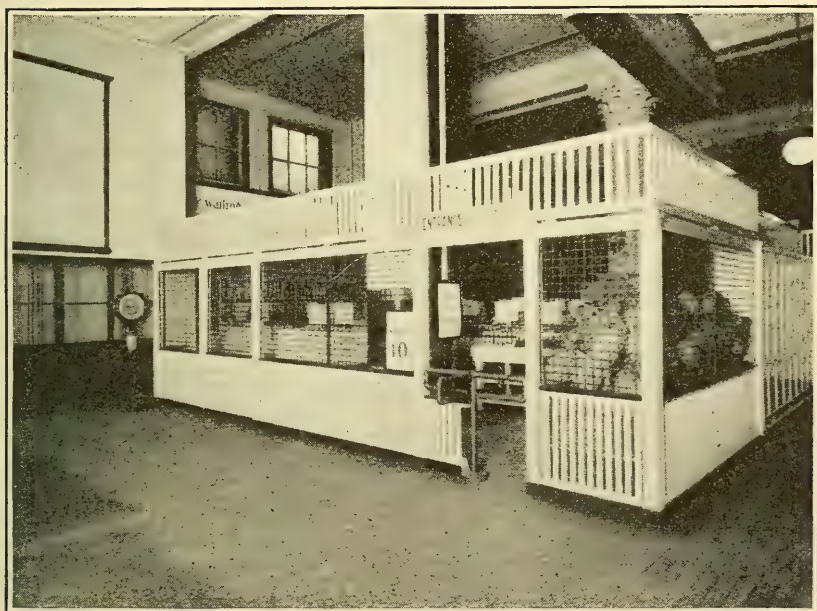


FIG. 1.—Entrance to self-serve grocery department in department store with one-way turnstile.

LAYOUT.

The store should be so arranged that the merchandise displayed for sale shall be in an inclosure that is provided with "one-way" entrances and exits in order that the movements of the customers can be controlled to facilitate the proper checking of the merchandise selected and payment for it. (See fig. 1.) This inclosure may take any shape made necessary by the shape and size of the store room. In its simplest form it would be as shown in figure 2.

The important part of this arrangement is the exit. At that point only does every customer come in contact with the personnel of the store. There the prices of his purchases are added, the merchandise

is wrapped, and his money is received. If particular attention is not paid to the facilities for performing these functions, serious difficulties are likely to be encountered. The number of exits necessary will depend upon the size of the business, the special conditions of the trade (whether it is steady or fluctuates considerably), and

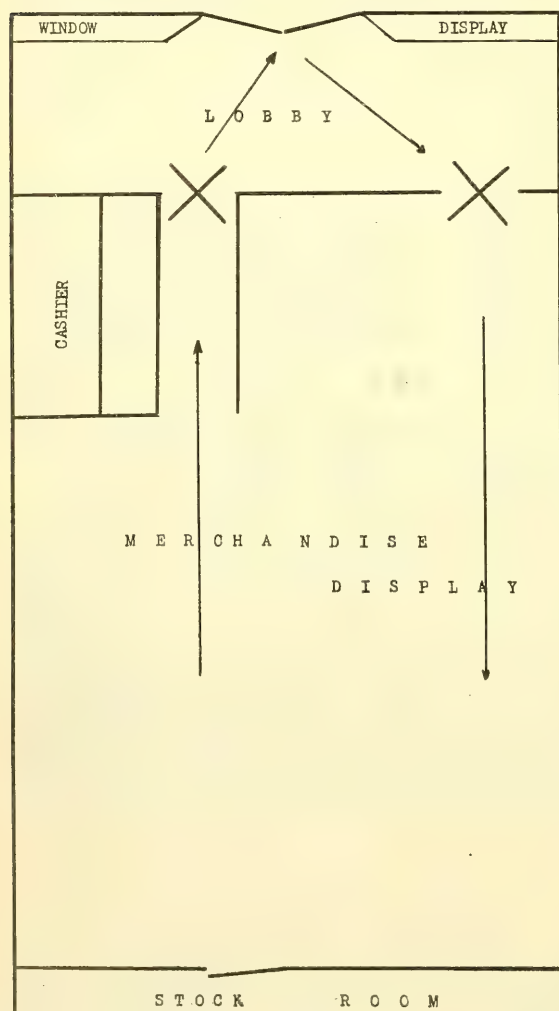


FIG. 2.—Diagram of a typical self-serve store, showing the entrance and exit.

the methods used in checking. When one experienced person does the checking, wrapping, and cashiering, it requires about a minute to take care of the average customer, but when two persons do this work it can be done in practically half the time. In some cases three persons or more are used, and this again reduces the time required.

Whether one, two, or three persons are stationed at the exit depends entirely upon conditions, as the principle involved is the same. When two persons are used, one usually checks and receives the money while the other wraps the merchandise. The employee who wraps usually calls the articles to the cashier, the latter entering the amounts on the add-

ing machine. When three persons are used, the first usually adds and totals the purchases, the second takes the money, and the third wraps. This plan is the least satisfactory, as it requires an extra handling of the merchandise. It should not be used unless it be impossible, because of the store arrangement, to add another exit,

or unless two persons at the existing exit are not able to take proper care of the customers. It is very much to be desired that the exits be of such number and arrangement that the customer will not be required to wait for any appreciable period, and this usually can be accomplished.

Figure 3 shows the simplest plan for an arrangement of the exits and cashier's desk in a one-exit store. This arrangement can be

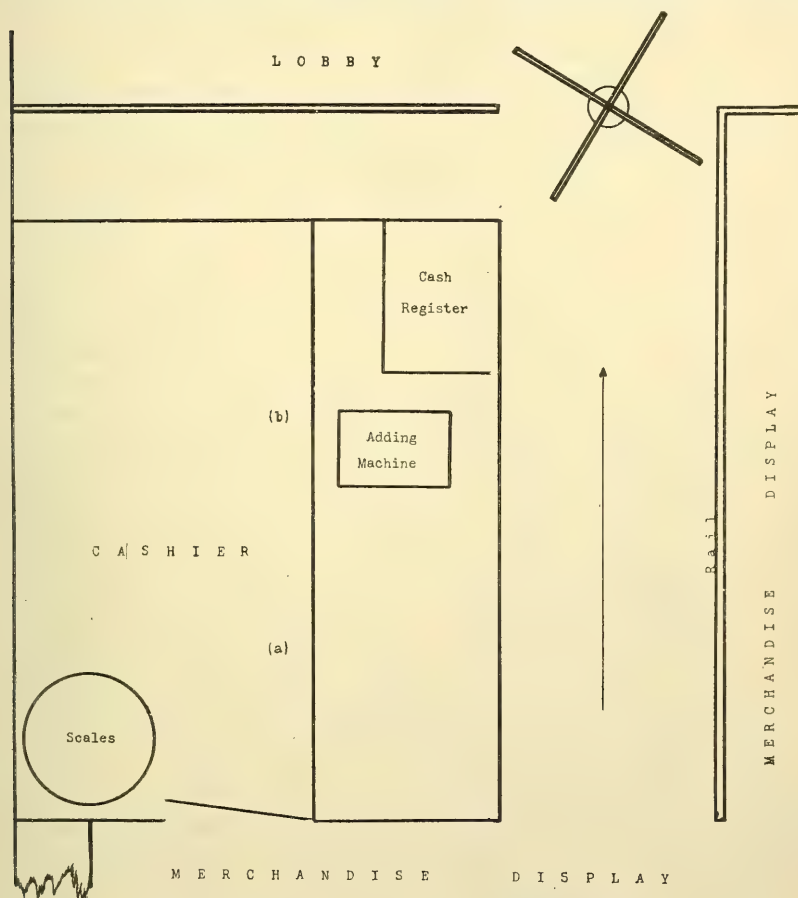


FIG. 3.—One-way exit where only one employee is used.

used with any number of cashiers or checkers by merely lengthening the counter sufficiently. But under the most efficient arrangement there should not be more than two employees for each exit. If there is only one employee, there should be a small cash register and adding machine, together with a scale, and equipment for wrapping the merchandise. An adding machine is not essential, but contributes materially to the speed and accuracy of the work. When two employees are used at the exit the following alternative plan is efficient:

The checker, standing at *a* in figure 3, takes the basket of merchandise from the customer and calls the price of each article to the cashier at *b*, who registers it on the adding machine. If there are any articles to be weighed, the checker weighs them on the scale at his side and then calls the amount to the cashier. After all the packages have been taken out of the basket the cashier totals the amount, presents the adding-machine slip, receives the money from the customer, and makes the change. Meanwhile the checker wraps the merchandise. By this arrangement the customer is taken care of in

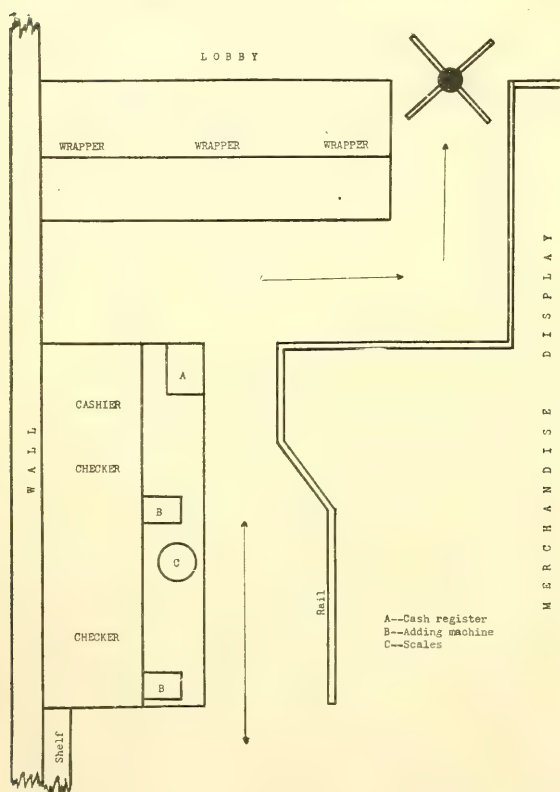


FIG. 4.—One-way exit where several checkers and wrappers are employed.

the least possible time. The only objection to using two employees at the exit is that during certain parts of the day there are not enough customers passing through to keep them busy. At such times one employee can serve both as cashier and checker and free the other for restocking the shelves and other work.

In wrapping it is advisable to use paper bags entirely. This is somewhat more expensive so far as the actual cost of paper is concerned, but the saving in time by this method more than offsets the increased

cost of the bags over paper and twine. The railing should be about $3\frac{1}{2}$ feet high and should extend the entire length of the counter. It should be so close to the counter that customers are forced to pass before the checker and cashier in single file. This prevents confusion and facilitates the proper checking of all purchases.

In case the volume of business is very large and the store is such that only one exit can be provided the plan shown in figure 4 is suggested. Such an arrangement, while not so efficient as the one

or two employee plan, is the most satisfactory under the conditions named. It would take two checkers and three wrappers to keep up with one cashier, and by this method the store would have an estimated capacity for doing a business of between \$100 and \$150 per hour. The aisle in front of the checkers and wrappers should be wide enough to allow two persons to pass comfortably, but that in front of the cashier only wide enough to permit one person to pass at a time. Under this arrangement the checker gives the adding-machine slip to the customer, who in turn presents it to the cashier for payment. After paying the cashier the customer passes on to the separate wrapping counter.

Figures 5, 6, 7, and 8 show arrangements for use when it is possible to provide two or more exits. The plan under which each exit is

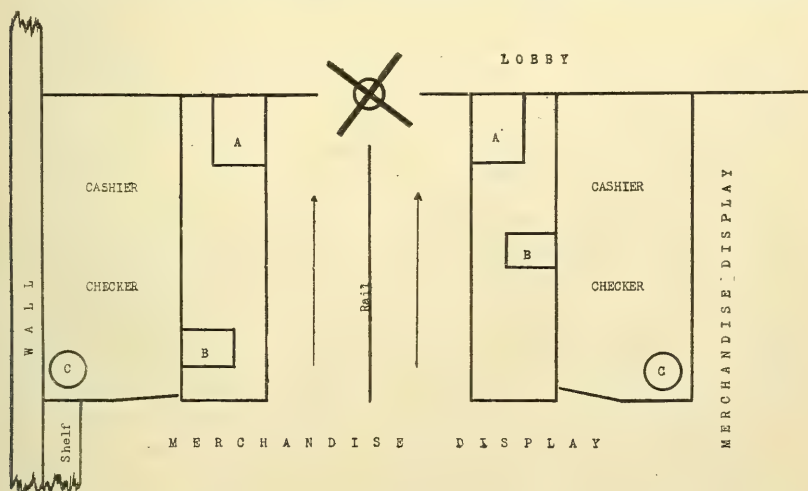


FIG. 5.—Diagram showing the arrangement of two exits. A, cash register; B, adding machine; C, scales.

operated is not different from that described under the one-exit plan. One or more employees may be used at each exit, depending upon the volume of trade and existing conditions. During the dull period of the day, one or two of the exits may be closed, thus liberating the operators for other duties, and increasing the efficiency of the store.

FIXTURES.

The fixtures used in the average self-serve store are simple and inexpensive. The elaborate use of show cases, scales, and other equipment is not necessary in the self-serve store. In fact, they could not be used to advantage, even if it were so desired. In their place are substituted tables and shelves for the display of merchandise. This probably means a reduction of from one-third to one-half in the investment required.

The shelves on the three sides are similar to those in service stores, though not so high, because all merchandise must be within easy

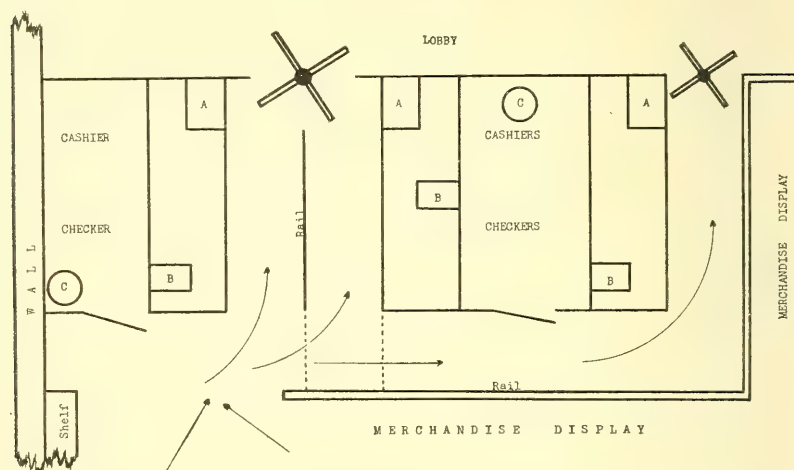


FIG. 6.—Three-way exit showing arrangement of aisles and equipment. A, cash register; B, adding machine; C, scales.

reach of the customer. Many of the dealers are using a deeper shelf than is ordinarily used in a service store, so that a greater quantity of each article may be placed in the same length of shelves and ordi-

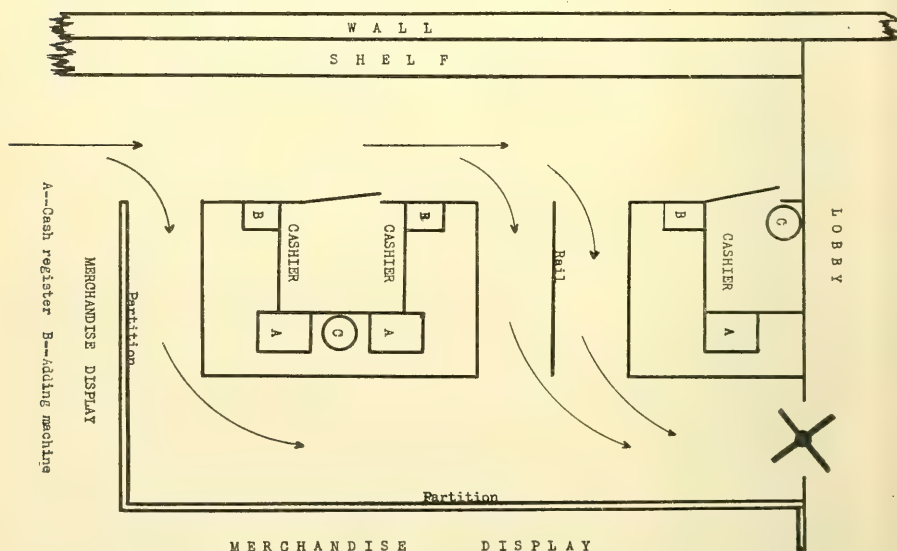


FIG. 7.—Three-way exit showing another arrangement of aisles and equipment. A, cash register; B, adding machine; C, scales.

nary storage saved. These wide shelves are possible in the self-serve store because there are no counters or regular show cases on the floor

and, therefore, no space used in aisles behind the counter for the clerks. In fact, under the self-serve plan a much greater merchandise display can be provided than in a service store with the same amount of floor space.

To a large extent, tables are used for the display of merchandise that can not be placed on the shelves. In some cases double-faced shelves are used lengthwise the store. One large concern controlling the operation of numerous self-serve stores has patented an arrangement of shelves, as shown in figure 8, whereby a customer is forced to pass before all the merchandise on display, a system which has its advantages and disadvantages. After a careful investigation, it is believed that tables used for the display of merchandise are more satisfactory than a series of tall shelves placed out on the floor. It would appear that a better plan than the use of either tables or high shelves is the use of double-faced shelves about 4 feet high in units from 6 to 10 feet long, with display space on top. Such an arrangement

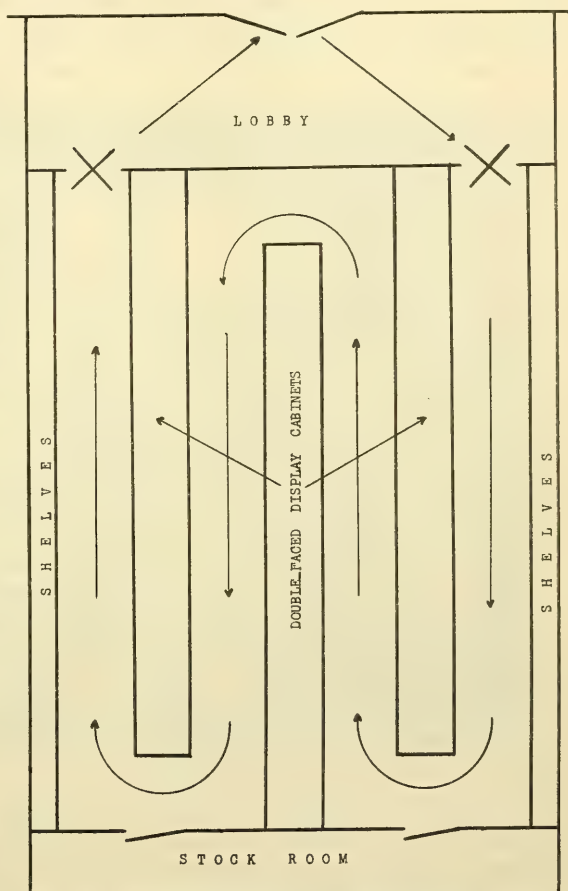


FIG. 8.—Showing arrangement of display shelves in a certain type of store. The circuitous passageway is patented. The cashier's booth is not shown.

preserves the advantages of both the high shelves and the tables, while doing away with some of the disadvantages of both. There are several advantages in the use of display fixtures of medium height in separated units, whether they be tables or shelves. The use of such fixtures affords a better view of the entire stock, is not so tiresome to the eye, and gives a much more pleasing appearance. Also, it allows less chance for thievery, as all customers are more easily seen by

store employees and by each other. Theoretically it would seem that the individual purchases would be larger if one is forced to pass before all the merchandise on display, but practically it has not worked out that way. The purchases seem to average about the same, whether one is allowed to proceed at will about the store or is forced around a certain path by the arrangement of tables or shelves.

The arrangement of the display fixtures should be decided by each operator, depending upon the size of the floor and his own desires, and is not vital to the success of self-service, except as it does or does not properly display the merchandise. Figure 9 shows the



FIG. 9.—Farm products displayed for sale in a typical self-serve store.

arrangement of tables in a very successful self-service store now in operation.

The number of scales needed in a self-serve store is considerably less than necessary under the service plan. Scales are necessary only at the exit and in the stock room where the packages are made up. If a considerable volume of business is done, an automatic scale should be placed in the stock room to save time and labor. As practically all bulk goods are put up in packages before being placed on the shelves or tables, and as a great many can be run through a weighing machine, such a machine is very desirable as well as economical.

An adding machine at the exit is not essential, but speeds up the work, insures greater accuracy, and means greater satisfaction to the customer. A suitable type of cash register, while not essential, will greatly facilitate the work of properly and efficiently taking care of the customer at the exit.

The entrance and exit should be so constructed as to allow only a one-way passage. This is effected by the use of turnstiles which provide for the entrance and exit of only one person at a time, and in one direction only. It is sometimes desired to keep a record of the number of persons passing through these turnstiles, both as a check and for statistical purposes. This can be accomplished by placing on each turnstile a small counting machine especially constructed for this purpose.

The refrigerator used for the display of such commodities as butter, cheese, and eggs is one of the most important items in the fixture account. An ordinary ice box can not be used advantageously because it does not permit the proper display of articles which must necessarily be kept in it. Where a considerable volume of business is done a large refrigerator may be built in as part of the partition between the salesroom and the stock room. The doors should be so hinged that they will automatically close tight (by the use of heavy springs) after they have been opened. Something similar to this can be followed out on a larger or smaller scale, depending upon conditions, with satisfactory results.

MERCHANDISE.

There are numerous problems in connection with the buying and selling of merchandise under the self-service plan that do not arise to such an extent under the service plan. These may be conveniently treated under the heads "Buying," "Grading," "Arrangement and display," and "Price display." Practically all of these problems exist in the service store, but their solution does not require such careful consideration, since the management can explain to the salesman, who in turn explains them to the customer. This does not always work out to the best interest of the service store, because of the human equation which enters in.

The information in regard to merchandise that the store wishes to impart to the customer is likely to be more carefully considered, and, therefore, more thoroughly worked out under self-service, because it is more difficult to impart the information under this condition. Under the service plan, as it is likely to be left too much to the initiative of the clerks, it is subject to variable interpretation. The lack of salesmen makes the selling of merchandise more a scientific than a human problem, and therefore in many cases it can be solved to

the greater satisfaction of both the customer and the dealer. Once the customer's confidence is obtained and maintained, through a proper solution of this problem, a better understanding will be had between him and the dealer. The word "substitution" often implies, to a certain extent, an unfair practice. But its use in this discussion implies only a necessary substitution (because of the inability to get the article desired) or one that is made in the best interests of the consumer, as when a buyer can secure an article of the same or better quality at a lower price than that paid for the article for which the substitution was made.

Many dealers make a practice of buying job lots, with little attention to their quality or uniformity as compared with the article substituted, price being the main reason for making the purchase. It is not meant that the actual buying of these job lots be discouraged, but it is believed that the majority of the dealers doing this do not fully take into consideration the selling cost, both in the increased effort necessary for their proper introduction and in the loss of customers' satisfaction, for there is a definite satisfaction on the part of the customer in being able to purchase an article with which he is already familiar, both as to quality and value.

During the past few years it has often been difficult to maintain supplies of certain lines of goods, either because of an actual shortage or the disruption of some phase of the distribution system. This has made the buying problem particularly difficult, and especially so under self-service.

BUYING.

The problems arising in connection with the buying of merchandise intended for sale under the self-service plan are not fundamentally different from those arising under the service plan, but they are magnified to a certain extent and need closer study on the part of the buyer.

Because of the absence of clerks in a self-service store, more attention must be given to supplying the customers with merchandise the quality and grade of which they will be readily able to recognize. This may be done in various ways, and should begin with the buying of the merchandise. Careful consideration must be given to brands, qualities, and grades. After the sale of a certain brand, or otherwise identified articles, has been established in any locality, the discontinuance of the sale of that article and the substitution of another article of the same quality, but with a different identification mark, causes a disturbance which can be overcome only after the expenditure of a considerable amount of energy. This energy may take the form of an explanation on the part of the sales person, or of advertising in various forms, or of the use of confidence, the building up

of which has required considerable effort. This substitution is most difficult to accomplish under self-service, but when made for a just purpose and when the proper methods are used is likely to be more successful than when done under similar conditions in the average service store.

GRADING.

That the grade or quality of all bulk goods, such as dried fruits, rice, coffee, cheese, and butter, may be readily distinguished, careful grading is necessary. In many cases the quality in any one grade need not be entirely uniform, except in so far as that grade can or can not be readily distinguished from another grade of the same commodity. The general principle of careful grading is applicable to any distribution of foodstuffs, because it makes for customer's satisfaction and is fair to all concerned, but it is discussed here as the means to facilitate price recognition on the part of the cashiers and checkers.

There is no difficulty in recognizing different kinds of merchandise, but there is difficulty in recognizing different grades where they are not differentiated by brand or labels but are ascertained only from inspection of the article itself. This applies to those bulk goods that are put up for sale in plain paper bags. Usually the price of each package is written on the bag itself. Of course, the grade must be ascertainable by the customer, and the various methods used for this purpose will be discussed under "Display." But when the package has been removed from its place on the shelf, where its location identifies its grade, there must be some means of definitely determining that grade from the package itself. The writing of the grade on each package involves the expenditure of too much time. Where two or more grades of the same commodity are for sale, the placing of the different prices on each package should suffice. But if any question arises as to the correctness of the price, the grading should have been done with such care that the question can be decided by a mere glance at the contents. This not only requires careful grading, but the elimination of closely associated grades.

In many stores operating under self-service this difficulty is avoided by the carrying of only one grade of these commodities. To make this solution successful, the grade must be selected that will most fully supply the demands of the majority of the customers. This selection requires careful study. Particular attention must be paid to the possibility of maintaining this grade, which is a problem for the store's buyer to solve. In fact, the limiting of a large percentage of this class of commodities to one grade is far from satisfactory.

The grading of fruits and vegetables, which is even more exacting than that of the products already mentioned, will be taken up in the section on "Perishable farm products."

ARRANGEMENT AND DISPLAY.

The arrangement and display of merchandise have troubled the operator of many a self-serve store. When first approaching the problem it would seem that the arrangement of merchandise would necessarily have to be very carefully worked out in order that a person may find the article desired out of some 600 to 1,000 different articles on display. Many elaborate plans have been made for such an arrangement, but the simplest seems to be the most effective. At first thought, looking for any particular article would appear to be like looking for the proverbial needle in the haystack, but it is possible to make the search a very simple matter.

Numerous concerns have arranged their merchandise alphabetically, working out elaborate plans on the assumption that the customer will experience less difficulty in locating the article desired. This would seem to be a good method on paper, but practically it does not work out so well. The main reason is because the possibility of putting so many articles under more than one section confuses the customer. For example, a customer is looking for a certain brand of corn flakes. He is not certain whether it is under C (corn flakes), B (breakfast food), or under the first letter of the brand named. If he looks under C and does not find it, he is not sure whether the store is out of it or whether it is under some other letter. Because of this arrangement the grocer may lose a sale and perhaps a customer. Another disadvantage of this method of arrangement is the fact that associated or similar articles may be in any number of different places, depending upon the completeness with which this alphabetical arrangement has been carried out—that is, whether only large groups or whether the constituents of those groups are arranged alphabetically. This classification of similar articles is not only inadequate but unattractive, since canned goods, bottled goods, and package goods are grouped together in every part of the store.

Probably the simplest, most convenient, and most pleasing arrangement is by groups of similarly appearing and closely associated articles. The commodities carried in the average grocery store readily divide themselves into six, eight, or ten groups of this kind. This grouping is the most natural, therefore the simplest and most convenient, from the dealers' as well as the customers' standpoint. Roughly, the stock may be divided into the following groups:

- No. 1. Canned goods.
- No. 2. Bottled goods.
- No. 3. Package goods.
- No. 4. Bulk goods (in paper bags).
- No. 5. Cracked goods (flours, meals, etc.).
- No. 6. Refrigerator goods.
- No. 7. Fresh fruits and vegetables.

The components of the first two groups need no explanation. The third group contains those articles put up by the manufacturer in cardboard or paper cartons, and the fourth, those bought by the store in bulk, but put in packages in the store itself. The sixth group is not limited to cold-storage goods, but includes those fresh goods which keep better in a cool place, such as eggs and butter—all goods to be found in the display refrigerators. The fifth and seventh groups need no explanations.

Under such an arrangement the customer has little difficulty in locating the articles desired. If one of the commodities is put up in cans, he proceeds to the canned-goods shelves, and if he does not find the article there, he feels reasonably certain that it is not in stock at the time.

The merchandise can be further subdivided into groups containing different brands of the same product, or groups of closely associated products. This is only the natural arrangement of the articles in the group, which any grocer would make. He would not place a certain brand of canned milk at one end of the canned-goods group and another brand at the other end, but would place all canned milk in the same section. A partial subdivision of the first group (canned goods) might be made as follows:

- | | |
|----------------|-------------------------|
| A. Milk. | F. Sirups and molasses. |
| B. Vegetables. | G. Baking powders. |
| C. Meats. | H. Oils. |
| D. Fish. | I. Cooking fats. |
| E. Fruits. | |

In a few cases it would be found impracticable to carry this grouping out to the letter. For example, chocolate is put up in both cans and cartons, and it might not be advisable to separate the two. In this case they could all be placed either under the canned-goods or package-goods group. If these two groups were adjoining each other on the shelf, it might be well to place such articles in a small section between the two groups. In this way there would be little danger of the customer overlooking them.

The actual location of groups, whether on tables or shelves, is a matter that can be decided by each operator according to his own conditions and ideas. Many self-serve stores have their canned and package goods on one side of the store and the bottled goods, together with the fresh fruits and vegetables, on the other side. The tables may be used for any class of merchandise, the general practice being to use them in connection with advertising. About the only important feature of the arrangement which should be followed under all conditions is that of placing the lighter articles near the entrance and the heavier ones near the exit. The reasons for such an arrange-

ment are obvious, as the customer is required to carry purchases to the cashier's desk at the exit.

The display of merchandise will be dealt with here only in so far as it is a means of identifying merchandise. Such articles as rice, beans, dried fruits, and many other bulk goods are usually put up in paper bags by the dealer before they are put on the shelves or tables for sale. That the customer may know exactly what he is buying, both as to quality and grade, it is almost imperative that he see the article itself, or a sample of the article. Any description that the dealer might place upon the package would not fully identify the goods. If every customer knew the exact quality of the articles carried and had complete confidence in the dealer, such an identification might suffice. But, unfortunately, this condition does not usually exist.

Some method must be used by which the customers may see the goods or a sample of the goods. The use of "window" bags is not practicable because of the expense involved and the lessened durability of the container. The only satisfactory means yet devised is the display of a sample which exactly corresponds, in both grade and quality, to the merchandise in the packages. This is usually done by suspending from the shelf above a small container having a transparent face. It is so made that the sample that it contains can be readily changed. Care should be exercised in placing the samples so that there will be no mistake as to the commodity represented. It is advisable to divide the shelves into sections of only sufficient size to hold the desired number of packages of any one commodity, or any one grade of that commodity.

PRICE DISPLAY.

All merchandise for sale in a self-serve store should be so marked that the customer will have no difficulty in determining the price. This can be done by marking the individual articles, or by having a price tag for each different kind or grade of article, so placed that there can be no misconception in regard to the article to which the price relates.

The main advantage of marking each article is that there can be no question as to its price and the cashier or checker at the exit does not have to remember it. This reduces the possibility of argument between the employees and the customers, thereby saving time and reputation, and also aids in the accuracy of the work at this point. But there are numerous disadvantages in this method, the greatest being the labor involved in marking the packages. This requires as much time, if not more, than is used in putting the articles on the shelves. The marking is usually done by pencil, either on the arti-

cle itself or on a small sticker that can be put on the article. There are special machines made for this purpose that print the price on a perforated, gummed sticker. This sticker may also carry the store's identification mark if desired. In opening up a case of goods to be placed on the shelves, the desired number of stickers can be run off on the machine and then put on the articles as they are taken from the case. This is the most satisfactory way of marking the individual items, as it not only makes a good appearance but helps to identify the article as being purchased at that particular store. Another advantage of this method over marking the price with pencil is that when price changes are made, another figure can be placed over the old price, whereas when marked with a pencil the old price has to be either erased or crossed out and the new one written on, which detracts from the appearance of the article. On many articles it is almost impossible to write the price so that it can be found readily by either the customer or the cashier.

The chief advantage of using a single price tag to apply to a number of articles of the same kind or grade is the saving of time effected over writing the price on the individual articles. Time is saved when the articles are first placed on the shelves, when any change in price is made, and at the cashier's desk. When a price change is made and a number of articles on which the change is made are on the shelves, the first method discussed involves the changing of many prices, while this method involves the changing of only one price. At the cashier's desk a considerable amount of time in the aggregate is involved in hunting for the price on each article. It might be thought that the cashier and checker would become so familiar with the prices that they would not have to look on the article for the price, but this is not as true as might be supposed. In the second place, the cashier and checker rely on this marking to determine the changes, and through force of habit will look for the price even on articles of which they know the price. Also, they might, if they should rely upon their memory, overlook price changes recently made, because under this method they are not necessarily informed of the changes.

The location of the group price tag is an important matter. The most common method is to place it on the edge of the shelf, as representing the goods on that shelf. But the customer does not always know that the tag represents the price of the goods immediately above, and when the goods on the shelf below are of such size or piled in such a way as to bring them near the bottom of the shelf above, there is likely to be confusion. The most satisfactory way is to suspend the tag from the shelf or cabinet so that its location will be immediately in front of the articles it represents. One method used is to hang the tags on a fine wire across the face of the shelves or

cabinets, about one-third of the distance from the shelf on which the goods are placed to the shelf above (fig. 10). The wire also prevents small bottled goods from falling out of the shelves. Another method suspends the tag diagonally from the corner of the section of the shelf or cabinet, or vertically from the shelf above, as shown

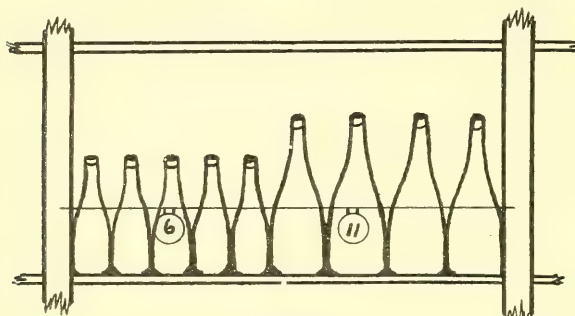


FIG. 10.

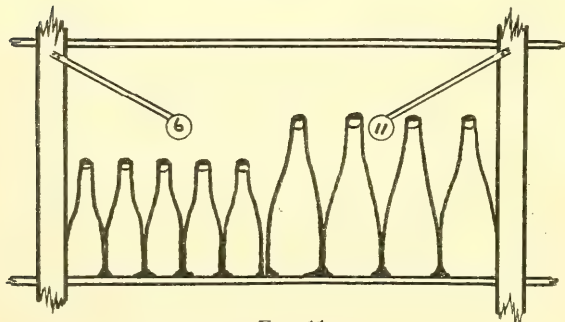


FIG. 11.

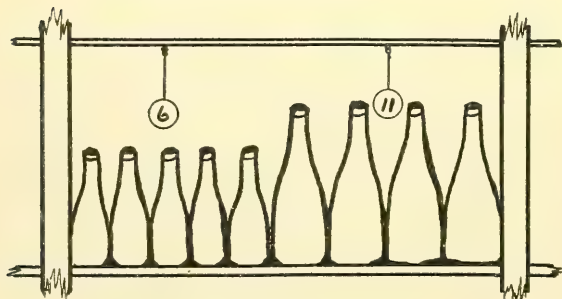


FIG. 12.

Diagrams shewing methods of attaching price tags.

SALESMANSHIP.

At first thought it does not seem that such a thing as salesmanship should enter into the operation of a self-serve store. But it does, and to a considerable extent. If this were not so, the introducing of new articles and the placing of special emphasis of certain kinds

in figures 11 and 12, respectively. This is satisfactory, except that since the tag is stationary it may interfere somewhat with the placing of the goods on the shelves and their removal by the customers. Probably the most satisfactory means of suspending these tags is by some swinging arrangement effected by the use of a screw eye or staple in the shelf above and a metal strip or wire suspends the tag. In this way the price tag can be swung to one side when necessary to place or remove articles directly behind it. It should be noted that certain swinging tags of the latter type have been patented.

of goods, which the dealer believes represent the best value to the customer, would be almost impossible. This salesmanship is brought about by the proper correlation between the outside advertising (newspapers, circulars, etc) and the display of merchandise in the store. This backing-up of the advertising is probably best effected by the use of display tables. Articles on the tables located nearest the entrance have more prominence than articles located in any other part of the store; therefore the use of tables so situated is most effective. By the constant use of the front tables to display articles advertised, or, where advertising is not extensively carried on, to display articles of exceptional value both as to quality and price, the customer comes to look upon the merchandise on those tables with special interest. If care is used in selecting the articles, so that in every case the customer's satisfaction is assured, the method can be made very efficient. In the case of one successful self-serve store the customers have apparently come to give as much weight to the fact that an article is displayed on a certain table as they would to the recommendation of a salesman.

In order that the customers who do not see the advertisements nor notice the articles on the display table may find those goods in their accustomed places, it is advisable to leave some of them on the shelves; so the tables should be filled from the stock room rather than from the shelves. Some dealers use numerous signs indicating the location of the various groups or classes of merchandise in an endeavor to aid the customers in locating their purchases. In the case of articles on the display tables, the large price tag is headed with the name of the article itself. Investigations have shown, however, that if the merchandise is arranged logically, customers have very little difficulty in locating their purchases where no signs are used except those stating the price.

PREVENTION OF THIEVERY.

Assuming that under the self-service plan, because of the accessibility of the merchandise, the attention of the public is more frequently called to the possibility of petty thievery or shoplifting and that this petty thievery does exist to a greater extent than in the service stores, the question is, How can it be most successfully combated? It has already been shown that under proper conditions thievery does not exist to such an extent as to make self-service impracticable; that is, the saving in the cost of operation and the elimination of other conditions existing under the service plan outweigh the loss which is assumed to be peculiar to self-service.

The loss varies greatly in different localities and under different conditions, depending apparently upon the class of trade to which the store caters. An idea as to its extent can be obtained by observa-

tion and by keeping a running inventory of certain articles which the dealer believes would be particularly susceptible to such thievery. If the latter method is to be used, it is well to pick out small articles which could be easily concealed and which are more or less expensive. A half dozen of these could be selected and the inventory taken of them at the beginning of the day's business. The kind, size, and brand of each article should be given to the cashier or checker at the exit, who would be required to list all those articles when presented at the exit by the customers. At the end of the day, another inventory should be taken and the number of items removed should be listed. If all articles are to be accounted for, these figures should



FIG. 13.—General view of a self-serve grocery store, showing both shelves and tables for display of goods.

agree with the cashier's or checker's figures. If there is a difference, either the goods were removed without being paid for, or else the cashier or checker failed to list all the articles presented by the customers. If this method is used a number of times and over a general line of merchandise, a fairly good estimate of the shrinkage by thievery can be obtained.

The instinctive fear of detection comes simultaneously with the act of taking anything for which no payment is intended to be made. Therefore, if the articles most likely to be taken are so placed that an effort must be made to reach them, there is less danger of their being taken. Another method commonly used is that of placing all

the smaller, more expensive articles in the close vicinity of the cashier's desk. This is a good plan not only because the cashier can watch the articles, but also because there are usually more people near the exit and the fear of detection is greater.

The store should be so arranged that an entire view of it may be had from either the cashier's desk or the stock room, or better, from both. The cashier should watch the customers during the hours of slow trade, and some one in the stock room during those hours in which the cashier is especially busy.

In almost any community there are likely to be some persons who make it their business to pilfer merchandise. Therefore, in opening a self-serve store, it is well to bend every effort to weed these undesirables out. This can be most successfully accomplished by employing a woman in the guise of an ordinary shopper to watch for these people. When they are apprehended it is usually considered best to prosecute them because they are a menace to the community at large. Great care should be exercised in determining whether or not the person under observation did actually and intentionally steal the goods, as an unwarranted accusation may lead to serious complications.

DEVELOPMENT OF LARGE VOLUME AND RAPID TURNOVER.

The desirability of obtaining full advantage of the principles of self-service by combining with them the development of large volume of business and rapid turnover has been mentioned. Some specific examples of businesses operated on that basis follow. The observations were made at various self-serve stores. The data do not represent exceptional cases, but were taken at random so as to show the general situation. A separate store is referred to in each of the numbered paragraphs.

(1) Sales were \$12,000 per week. Twenty-five people were employed, of whom four were checkers, two cashiers, and six wrappers. Only one exit was used and it was estimated that under this plan the store had a capacity of \$250 per hour, which was actually reached during some of the busiest hours of the day.

(2) One store on a Saturday did a business of \$2,220, with eight employees, of whom four were boys not employed during the week. This was done with only one exit, at which there were one cashier and two checkers. The number of customers was 2,965. This is an average of $3\frac{1}{2}$ customers per minute, each customer's purchase averaging nearly \$1. During the busier hours of the day the cashier and checkers handled as many as 8 to 10 customers per minute.

(3) The store's sales were \$5,000 for the week. In the store were a small meat department and a pastry department on the service

plan. Each of these departments had one clerk. Besides these there were 8 employees, consisting of the manager, cashier, 2 checkers, 1 clerk in charge of the parcel-checking room where customers were required to check all parcels they brought into the store before being allowed to make their purchases, 1 clerk putting up package goods, 1 stock clerk, and 1 information clerk. All of these clerks were women, with the exception of the manager, who was also the proprietor.

(4) The store's sales averaged \$700 per day for the first five days of the week and were \$2,200 on Saturday, making the week's total \$5,700. This volume was handled by only 4 men throughout the week.



FIG. 14.—Exit in large self-serve store. At the counter the customers' selections are checked, paid for, and wrapped.

This exceptional showing was made only through a very efficient organization. Three exits were used, with only one clerk at each. If the customers in the store were of sufficient number to require only one exit in operation the other two were closed and the clerks immediately went back to work on the stock. Thus the number of exits used was varied with the number of customers in the store, thereby utilizing the full time of all the employees. Of course, each Saturday night the stock was much depleted and the most of the work for the first five days of the next week consisted of restocking the shelves for the next Saturday.

(5) The store's sales were \$8,000 for the week. There were 12 employees, consisting of 3 men and a boy keeping the stock up, 2

cashiers, 2 checkers, 1 man in the stock room acting as receiving clerk and stock man, 1 head clerk who bought all the fruits and vegetables and looked after the merchandise display, etc., 1 manager, and 1 office girl.

HANDLING PERISHABLE FARM PRODUCTS.

There has been a great deal of discussion as to the possibility of handling perishable farm products under the self-service plan. Such products as butter, eggs, and cheese present little difficulty as to handling, but meats and certain fruits and vegetables are somewhat difficult to handle under self-service, in fact so much so that numerous self-serve stores handle them in a separate department under the service plan. The objections to handling them under self-service are that the customers, in selecting their purchases, pick over the goods, selecting only the best and leaving a considerable quantity of merchandise which has to be reduced in price in order to move it, and that the customers damage a considerable quantity in selecting their purchases.

It is practically necessary that a store handle the more perishable products, especially fruits and vegetables. A very few stores do not handle them, but they are not usually successful. Grocers often say that a good display of fresh fruits and vegetables will do more than almost anything else to insure a good trade and that it stimulates trade more than a special sale of staples, even though a better value is given in the sale of the staples.

Fruits and vegetables are handled in numerous ways under self-service, but only a few of these methods have been successful. Because of the usual methods of handling fruits and vegetables which are not carefully worked out, prices on those articles have been relatively higher than other foodstuffs. The public is always attracted by a good display and reasonable prices on these commodities, and the dealer handling them properly should be better able to meet competition on other lines.

Of the problems in connection with handling fruits and vegetables under self-service, some are peculiar to that mode of merchandizing, while others are involved in the handling of fresh fruits and vegetables under any conditions.

BUYING AND GRADING.

Certain fruits and vegetables are more suitable for handling under self-service than others. In general, the products of this class that can be handled most successfully are those that are not highly perishable and easily bruised, and which are, at the same time, of considerable value per unit. Citrus fruits may be taken as representing this group. Such products as potatoes, on the other hand, though not

easily injured, are heavy and bulky in relation to value, and since they must in most cases be carried by the purchaser, they constitute more of a problem under self-service. Potatoes, however, are practically a necessity in the average American household, and in spite of the drawback of bulkiness considerable quantities are sold through self-service stores.

A great deal of difficulty in the handling of fresh fruits and vegetables under the self-serve plan can be overcome by careful buying. The buyer should have in mind the problems arising from the handling of such products and do his buying accordingly. He should buy only those commodities which have been very carefully graded and only those grades which can not be readily confused. Take, for example, oranges, which usually come 96, 100, 126, 150, 176, 200, 216, 252, 288, 300, or 324 to the box. It would be an unwise policy on the buyer's part to choose the sizes 176, 200, and 216 for sale at different prices according to the size of the oranges, because it would be almost impossible for the cashier or checker to distinguish the size and make proper charge for those oranges. It would be much better, if he wished to have three sizes, to buy one size around 100, one around 200, and one around the 300 size, so that the cashiers and checkers would be able to distinguish readily the different sizes.

Special attention also should be paid to obtaining a uniform quality throughout any particular grade. The more uniform the quality, the less the customers will handle or pick over the merchandise, which will, of course, reduce the loss through spoilage or necessary price reductions.

The grading of fresh fruits and vegetables can be done in the store after they have been purchased, but the proper selection of these products at the time they are bought will help considerably. If little attention is paid to the buying, the products will lack uniformity, and in regrading at the store it may be difficult to sort them into distinct classes. Unless this can be done loss is likely to occur, either through the unnecessary handling of the product by the customers or the mistaking of the grade by the cashiers and checkers.

DISPLAY.

After the merchandise has been properly graded it should be displayed in such a manner as to attract the attention of the customers and at the same time to meet the special requirements of the product. Probably the most effective display is by the use of tables or similar unit fixtures, the tops of which may be divided into bins for display of more than one kind of article on the same table. In some instances fresh fruits and vegetables have been put into packages and a sample of the contents displayed. This has proved unsatisfactory, as cus-

tomers apparently are not willing to buy such articles from the samples. They wish to see the actual contents of the package and will usually break tied packages open before purchasing them. This causes waste and also prevents the use of the products for attractive displays.

Fruits and vegetables may be divided into groups, according to the methods of handling that seem most satisfactory. Among those that can be most satisfactorily sold under self-service are oranges, lemons, and grapefruit, cantaloupes, bananas, cabbage, eggplants, cucumbers, peppers, and certain types of apples. Lettuce and cauliflower also are dealt in successfully by some self-service establishments, but they are more easily injured by handling than the other products named. Most of these products are usually exposed in bulk and sold by count, but a few, such as cabbage, cauliflower, and bananas, might be sold by weight, while peppers might be sold by the small basket.

In the case of certain products, display in baskets is practically a necessity because of the smallness of the units or because the products are too perishable to stand bulk display and picking over. In this group may be included lima beans, either shelled or in pods, green peas, string beans, Brussels sprouts, tomatoes, peaches, pears, plums, cherries, grapes, berries, and cranberries. Of course, when the small fruits which may be eaten without preparation are displayed, the temptation to petty pilfering is considerable. For this reason some self-serve stores do not deal in such products, confining their basket trade to vegetables, the larger fruits, and to such small fruits as cranberries, which require cooking. The placing of berries, cherries, etc., near the cashier's desk probably would reduce the pilfering of such products. At least one manager of a self-service store has solved this problem satisfactory to himself by placing baskets of small fruits in his glass-door refrigerators. He finds that customers will not open the doors to pilfer.

Where berries and other small products are displayed in pint or quart boxes, the containers may be sold with the fruit, the whole package being slipped into a paper bag by the wrapper. In the case of many of the products mentioned as best displayed in baskets, however, especially in the case of baskets containing more than a quart, the contents usually are poured into bags by the wrapper, the baskets being retained for repeated use by the store.

A third group, practically confined to vegetables, may be described as semibulky products usually bunched. In this group are green onions, young beets and carrots, oyster plants, radishes, asparagus, rhubarb, celery, and sweet corn. Most of these products can be sold satisfactorily under self-service when exposed in bins or on tables. Sweet corn probably can be sold less satisfactorily under self-service than any other of the products in this group. Customers usually

insist on tearing open the ears and even on squeezing the kernels. For these reasons, some self-serve operators make no effort to sell sweet corn. Others attempt to solve the problem by exposing only a relatively small number of ears at a time, replenishing the supply only when the preceding lot is almost exhausted.

Loose greens, such as spinach, kale, mustard, and endive, can not be dealt in as easily under self-service as some of the other vegetable products, but when the matter is handled rightly these products, too, may be sold successfully. One of the best methods of handling greens is to expose them in bulk in bins or trays with paper bags of several sizes in reach, pricing the products by the pound. The purchaser can then place in a bag about the quantity desired and the purchase can be weighed by the checker. A number of products of the other groups also may often be sold most satisfactorily by weight.

Several methods have been tried in handling under self-service the bulkier vegetables of low unit value, such as potatoes, dry onions, mature beets, carrots, parsnips, and sweet potatoes. In some stores such products are exposed in bulk with large paper bags, into which the purchaser may place the units desired. In other stores the amounts for which there is the greatest demand are placed in bags, often with the tops open to permit inspection. Still other operators display the products in baskets of various sizes, from which they are transferred to bags by the wrapper. On the whole, the most satisfactory method seems to be to expose some of each product in baskets in connection with a bulk display accompanied by empty bags. Such an arrangement meets the desires both of those customers who wish to pick over the stock and those who prefer to save time and trouble by taking a filled container.

In pricing many fresh fruits and vegetables, it may be found advisable to base the price on a small unit, as making the price per orange. This may have a tendency to reduce the size of each sale, but it is much more satisfactory to the customer, as it is always easier for him to figure out what three or four oranges will cost than when the price is quoted per dozen.

The placing of tender-skinned fruits or vegetables in display containers which are likely to cause injury and consequent decay to the product, such as rough wire baskets, should be avoided.

SPOILAGE.

The percentage of spoilage of fresh fruits and vegetables has been variously estimated from 1 per cent to 10 per cent. Few accurate figures are obtainable, but probably the percentage of spoilage depends more upon the method of handling the fresh fruits and vegetables than upon any other one factor. In order to reduce this percentage of spoilage to a minimum, careful buying as to price and

quantity is essential so as to insure a turnover of once a day on the more perishable products and at least once a week on the more staple products.

The average dealer, realizing there is a considerable loss from spoilage and wanting to be on the safe side, marks his more perishable products up perhaps about 50 per cent. This, of course, tends to discourage purchases and causes slow movement, which automatically increases the spoilage. Therefore, when this average dealer is asked what his percentage of loss through spoilage is he can show from his records, if he keeps them, that his spoilage amounts to such and such a high percentage. But this does not necessarily prove that such a percentage of spoilage is anywhere near the minimum that can be obtained. Operators who recognize the value of modern merchandising methods completely reverse this procedure. They examine the articles carefully before they are purchased and buy only sound products; they buy only in sufficient quantities to last for a day or a week, depending on the nature of the products, and they assume that losses from spoilage will be almost negligible if products are sold rapidly. They are enabled, therefore, to make very little allowance for spoilage and to set relatively low prices. These low prices stimulate sales, so that the products are moved into consumption before they have time to spoil.

In one of the self-serve stores studied considerable attention was given to the marketing of fresh fruits and vegetables, and they were handled in a very efficient manner. Careful records were kept of the loss through spoilage, both in the way of a reduction in price to move partially spoiled or damaged products and absolute loss resulting from spoilage, and it was found that this percentage of total spoilage amounted to only 2 per cent of the total sales of fresh fruits and vegetables. This, of course, does not take into consideration the loss through such factors as evaporation, but represents only the visible loss through spoilage and mark-downs necessary to move certain of the more perishable products the same day they were purchased. This loss ranged from 1 per cent on potatoes and 3 per cent on citrus fruits to 20 per cent on Tokay grapes shipped from California. These figures were taken from the records of one month's operations during the latter part of the summer.

ACCOUNTING.

The existence of self-service is primarily dependent upon its ability to sell merchandise to the consumer at a lower cost than by other methods of distribution. In order that this may be most satisfactorily accomplished, the economies of the plan itself should be further emphasized and supplemented, as has been pointed out, by oper-

ation of a large-volume business on a small margin of profit with rapid turnover. On this basis a lower cost to the consumer would be made possible by a saving in operating costs, plus a saving in net profits, for the dealer could secure a sufficient return from his large volume of business by reduced percentage of net profits. In other words, the dealer could get his net income from many small profits instead of from a few large profits.

If this plan of operation is to be followed a closer watch of the business must be kept, because any variation in the gross profit obtained or in the cost of operation would have a relatively greater effect on net income. For example, two dealers receive the same income from their investment, one doing a business of \$35,000 per year on the service plan and taking 4 per cent net profit, while the other does a business of \$70,000 under the self-serve plan and takes 2 per cent net profit. If in both cases the gross profits fall 1 per cent or the cost of operation increases 1 per cent, measured on net sales, the dealer doing twice the business on half the margin would lose 50 per cent of his profits, while the other dealer would lose only 25 per cent of his profits. This is shown in the following tables.

	Percent- age of net profit.	Sales.	Net profit.
Service plan.....	4	\$35,000	\$1,400
Self-serve.....	2	70,000	1,400

If gross profits decrease 1 per cent or cost of operation increases 1 per cent:

	Percent- age of net profit.	Sales.	Net profit	Percent- age of loss
Service plan.....	3	\$35,000	\$1,050	25
Self-serve.....	1	70,000	700	50

No particular accounting system is advised and therefore none will be dealt with in detail, except that portion of the ordinary accounting necessary to obtain the special information desired. The obtaining of special information is not essential under the self-service plan, because of the self-service aspects, but on the contrary is desirable under any method of business. The matter is mentioned here only because of the particular significance of such information in connection with operation on a small margin of profit.

CLASSIFICATION OF EXPENSES.

In every business, no matter how small or of what nature, sufficient records should be kept so that the net profit or loss can be de-

terminated accurately. The methods by which this can be determined vary greatly, some being very simple and others very complex, depending upon the amount and kind of information desired. The subdivision of expense accounts is all that will be dealt with here, since that is of special interest, and also since accounts of this nature are not kept as commonly as might be considered desirable.

In order that an intelligent view of the cost of operation may be had, the expenses should be subdivided into 10 or 15 accounts. An enumeration of the possible accounts, together with a brief description of what they should consist of follows.

1. MANAGEMENT.

To the management account should be charged all office supplies and expenses, such as telephone, stationery, and postage, together with office wages and management salaries. A special buying-expense account is sometimes maintained in establishments large enough to warrant handling the matter in this way. It is assumed here, however, that buying expenses will be included in management expense. To this account should be charged the actual management salary where such a salary is paid. When no management salary is paid, the account should be charged with the salary the manager could command when working for some one else, and the offsetting credit should be made to the owner's personal (drawing) account, to which all checks by him for personal use should be charged.

2. RENT.

Actual expenditures for rent should be charged to the rent account.

3. INTEREST.

Interest paid should be charged to an interest account. Some accountants treat interest not as a part of operating expense, but as a deduction to be made from net operating profit, in order that the true net income may be ascertained. (See Form I, p. 50.)

4. INSURANCE AND TAXES.

To the insurance and taxes account should be charged all taxes on the stock or equipment or on the volume of business, the cost of local licenses, and Federal revenue taxes except income taxes. The cost of fire insurance on the stock and equipment, employees' liability insurance, and burglary insurance should be charged to this account. Where premiums are paid for fire insurance on the building, however, they should not be charged to this account, but to a realty operating account. If the insurance and taxes account is properly kept, insurance and taxes can be separated readily for income-tax purposes.

5. HEAT, LIGHT, AND POWER.

The cost of all fuel and electricity used in heating and lighting the store and operating power machines should be charged to the heat, light, and power account; also supplies or repairs relating to heat, light, and power.

6. REPAIRS.

Repairs on fixtures may be charged to the repairs account or to the realty operating account.

7. DEPRECIATION.

A depreciation account yearly should be charged off to show depreciation, 10 per cent of the value of the fixtures.

8. WAGES.

To the wages account should be charged all wages paid to those persons connected with the actual handling of merchandise, such as stock men, checkers, and cashiers.

9. ADVERTISING.

All expenditures for advertising, trading stamps, or premiums or demonstrations, plus the value of any time spent by the management in superintending this part of the work, should be charged to the advertising account.

10. ICE AND COLD STORAGE.

Cost of ice, or if a cold-storage plant is operated by the store the cost of its operation, should be charged to the ice and cold-storage account.

11. WRAPPING.

The cost of all paper, twine, and paper bags is to be included in the wrapping account. In many cases this expense is charged to the cost of merchandise, but such procedure is unsatisfactory, since it gives an erroneous idea of the returns from merchandise sales.

12. MISCELLANEOUS.

The miscellaneous account should include such expenses as water, laundry, cleaning materials, labor of cleaning, contributions to charity, dues to trade associations, subscriptions to trade periodicals, thefts of money or equipment, and any other small expenses incident to the operation of the store. If desired, certain of these items may be placed in separate accounts, thus making the information even more complete.

In order that a complete summary of the operation over any period may be obtained, the use of Form 1, page 50, is suggested. The

preparation of this summary is explained in the following paragraphs.

13. OPERATING STATEMENT.

The "sales" figures should represent only the actual or net sales; that is, the money taken in less any allowance to customers for spoiled or unsatisfactory goods purchased or for containers or purchases returned.

Opposite "purchases" should be entered the total billed cost of merchandise bought during the year, less cash discounts received and less allowance received from wholesalers for unsatisfactory goods.

"Inward transportation" should include freight, express, and drayage on incoming merchandise paid by the business.

The "inventory at end" should show the billed cost of the merchandise on hand, less the sum of physical depreciation, market declines below billed cost, and the average percentage of cash discount received. Inventories should never be taken at market prices where such prices are greater than billed cost.

The "inventory at end" is subtracted from the "cost of goods handled," leaving "cost of goods sold." The latter figure is subtracted from the "sales," leaving the "gross profit," which represents the difference between the selling and cost price of goods sold during that period. The totals of the various subdivisions of the expense account are added, and this final total is subtracted from the "gross profit," leaving the "net profit or loss." The column at the right may be used to write in the percentages which the items bear in relation to total sales, the latter being 100 per cent. The chief value of these percentages is that reports covering different periods can be more readily compared.

ASCERTAINMENT OF SHRINKAGE.

The accounting methods already discussed will enable a manager to see how much profit he has been making, his turnover, volume of business, and the expenditures for each of the several classes of expense. The percentage of expense to sales obtained in this way, however, can not be used alone for determining the average percentage of sales that is necessary as a mark up in order to meet the expenses of the business. Certain actual losses in the goods themselves must also be considered.

Spoilage of goods during handling, evaporation in the case of some goods, thievery, waste, and overweight cause a less quantity of goods to be sold than are bought. It may also be necessary to lower the price originally settled upon in order to meet market declines in the wholesale market or competition. Other goods may be marked down for advertising purposes.

Price declines, mark downs for advertising purposes, spoilage, evaporation, overweight, waste, thievery, and net shortage owing to cashier's errors together constitute what may be called "shrinkage." In the case of department stores or chain stores it may also be necessary to consider transfer to other departments or other stores.

In determining the average percentage of mark up necessary shrinkage must be considered in addition to the average percentage of expense burden.

Because of the many diversified lines in the grocery business and the small size of the usual sale it is not practicable to keep account of shrinkage by perpetual inventory methods, but it is practicable by means of a stock-control operation to determine the shrinkage for a representative period, and this will enable the manager to estimate the shrinkage over a longer time.

If the inventory of stock at the end of the period during which the stock-control operation is carried on is subtracted from the sum of the inventory at the beginning, plus purchases, all three items at retail valuations, the result is the retail value of all goods disposed of during the period. The subtraction from this figure of total sales will give the total shrinkage from all sources during the period. Making separate records of retail price declines, of mark downs for advertising purposes, of mark downs for spoilage, and of transfers, these classes of shrinkage can be accurately determined. Mark ups can also be recorded. If the classes of shrinkage mentioned are subtracted from total shrinkage, the corrected retail value of goods sold will be ascertained. When net sales are subtracted the balance will be miscellaneous shrinkage, which is made up of evaporation, overweight, waste, thievery, and shortage, if any, owing to cashier's errors. The details of this operation will be discussed further. Form 6 summarizes the procedure.

If the stock control is kept by classes of goods, such as fresh fruits and vegetables, dairy products, cured meats, and other groceries, the shrinkage from each source and the total can be accurately determined for each class of goods handled. In the same way shrinkage can be determined on individual items if desired.

Under present competitive conditions it may not always be possible for a merchant to add the exact mark up on each item that would be necessary to cover the exact cost of handling that particular article. But if a merchant knows exactly where his losses occur on one article, and how much, he is in a much better position to so manage his business that these losses will be reduced to a minimum.

In arriving at the retail value of purchases for the period, only that stock should be considered which is actually added during the period,

without regard to whether the payment is made before, during, or after the period during which the operation is carried on.

Changes in retail prices are recorded on a form similar to Form 2, "Stock Control Adjustment—A." A new copy of the form can be used each day, or the same one used until it is filled. The manager or proprietor should fill out the first five columns—Date, Description of Article, Unit, Old Price, and New Price—for each article on which a change in price is made. The form should be used as the authorization for the price change itself to make sure that it will be properly filled out. After the above entries have been made by the proprietor for all articles on which he wishes a price changed, the form should be given to the stockman, who makes the actual price change on the merchandise itself. At the time of making this change he should count the number of articles, both on display and in the stock room, and enter the number on the proper line under "Inventory." After this has been done the sheet should go to the cashiers and checkers in order that they may become acquainted with the new prices. If desired, each of these employees should be requested to sign his name on the back of the sheet to show that he has been informed as to the changes.

If this system is used in connection with a chain-store organization it might be well to leave the "old price" blank and have the managers of the branch stores fill this in as they make the changes. This would inform the central office as to whether the managers had been getting the proper price.

When the form has been returned to the office the unit change in price should be entered in the proper column under "Change in price." This should then be multiplied by the inventory and the product entered in the proper column under "Change in stock control." In order that the procedure may be more readily understood, the following examples are given: One showing an advance in price and the other a decrease in price. The information is given as it would appear on Form 2, reading from left to right.

(1) July 2, Blend A coffee, 1 pound, old price 35 cents, new price 38 cents, 53 pounds. Under "Change in price," 3 cents would be entered in the "Up" column. This, multiplied by the inventory, should give \$1.59, which should be entered under "Change in stock control" in the "debit" column. The reason for this is that the 53 pounds had been charged in at only 35 cents per pound but is to be sold at 38 cents per pound; and, therefore, the charges to the stock-control merchandise account, in order that the latter may correspond with the sales account, should be increased by this difference, or \$1.59.

(2) July 3, Jonathan apples, 1 pound, old price 7 cents, new price 5 cents, 136 pounds. Under "Change in price," 2 cents would be entered in the "Down" column. This, multiplied by the inventory,

would give \$2.72, which should be entered under "Change in stock control" in the "credit" column. The reason for this is that the 136 pounds had been charged in at 7 cents per pound but are now to be sold at 5 cents per pound. Therefore the stock-control merchandise account, in order that the latter may correspond with the sales account, should be credited with this difference of \$2.72.

At the end of the period the totals of the debit and credit columns should be added and subtracted, respectively, as indicated in Form 6 ("Mark-ups" and "Mark-downs"). These figures are valuable in that they show the trend of the market as well as adjust the merchandise account of the stock-control operation to correspond with the sales.

That price reductions for special-sale purposes may be similarly taken care of, Form 3, "Stock Control Adjustment—B," is recommended. This form should be used in connection with special sales for advertising purposes and not for special prices given because of "good buys," competitions, etc. The first five columns are similar to those of Form 2, except for the heading of the fifth column, which is "Special" instead of "New"; but the entries in this column would be similar in either form. As these special sales are for a short duration, usually one day, and are not intended as permanent, it is necessary to take an inventory at the beginning and ending of the sale in order to determine the number of articles sold at that special price. This inventory should be taken at the time the price is changed on the articles themselves. If the sale is for one day only, it might be necessary to take inventory of only those articles on the shelves or display tables. In this case it would be necessary to keep an accurate record of the number of articles taken from the stock room during the day of sale for the purpose of replenishing the shelves.

The number of articles on hand at the beginning of the sale plus the number received or placed on the shelves during the sale, less the number on hand at the end, would represent the number sold during the sale, and should be entered in the column "Quantity sold." The difference in price per unit would be entered under "Mark-downs," and this, multiplied by the quantity sold, would be the amount to be credited to "Stock control." From the nature of the sales, there would be no "Mark-up"; therefore the columns "Up" and "Debit" on Form 2 are not necessary in this form. The total of the credits to "Stock control" should be subtracted as indicated on Form 6.

As with Form 2, the information obtained from this record is of value aside from that of its use in connection with the adjustment of purchases at the retail price. It shows just how much money has been given away, because of reduced prices, for advertising purposes. In a great many cases this amount is far in excess of what it is believed to be. Whether or not this loss should be charged as a cost

of advertising can be left to the judgment of the operator. Knowing the cost, not the final disposition of it, is the matter of real importance.

Another factor in the shrinkage of merchandise is spoilage. This can, and should, be segregated, as it is an important factor and one of which very little is known. It can be segregated by the use of Form 4, page 51, "Stock control adjustment—C." The merchandise handled may be divided into four classes, as follows: Fresh fruits and vegetables, cured meats, dairy products, and other groceries. A separate sheet of Form 4 should be used for each class. The name of the class should be entered in the upper left-hand corner of the form in the space provided. It is evident that in order to have the merchandise account at retail comparable to the sales that account should be credited with the loss of sales owing to spoilage, whether this spoilage is complete or only partial, the latter necessitating only a slight reduction in the selling price. The method of using this form is similar to that of using the forms just described, except that it is filled out by the man in charge of the merchandise which has spoiled. Under partial spoilage is also included any mark downs necessary because of "picked-over" perishables. While these may not be decayed, the size and quality might be such that the original price would have to be reduced in order to move them. This is a common circumstance and one which is usually taken into consideration in the original selling price. In order that entries on this form may be made clear two examples will be given, one in which the spoilage was complete and one in which it was partial:

Example 1.—Fifty 2-pound baskets of tomatoes (a total of 100 pounds of tomatoes) were put up for sale at 15 cents per basket. The merchandise account was charged \$7.50, as that would be the total selling price. After 30 of these baskets had been sold at 15 cents each, it was necessary to sell the remaining 20 at 10 cents each, either because partial spoilage made them of inferior quality or because it was seen that they were selling too slowly at 15 cents and might spoil before they could be sold the next day. The following entries would be made on Form 4: Date; tomatoes; 2-pound baskets; old price, 15 cents; new price, 10 cents; inventory, 20; mark downs, 5 cents; credit stock control, \$1.

Example 2.—If, at the end of the day, 5 baskets were left which were so badly spoiled that they had to be thrown out, the entries would be: Date; tomatoes; 2-pound baskets; old price, 10 cents; new price, 0 cents; inventory, 5; mark down, 10 cents; credit merchandise account, 50 cents. The money received for these 50 baskets of tomatoes would be 30 at 15 cents, or \$4.50; and 15 at 10 cents, or \$1.50; the total being \$6. The merchandise account was originally

charged \$7.50; but, through this adjustment, it would be credited with \$1 and 50 cents, being a total of \$1.50, leaving the net charge to the merchandise account \$6, which exactly corresponds with the sales account. Differences could occur in these two accounts in only two ways: (1) Some of the baskets might be taken without being paid for; or (2) the clerk in filling the baskets might put more than 2 pounds in each. The latter situation could arise only if the selling price had been determined at $7\frac{1}{2}$ cents per pound before the baskets were made up and there were more than 100 pounds of tomatoes in the lot charged in. If there were exactly 100 pounds all of the 50 baskets could not be filled, of course, unless the average quantity of tomatoes in each was 2 pounds.

If the retail value of the stock sold is kept by the four classes mentioned in connection with the spoilage record, i. e., fresh fruits and vegetables, dairy products, cured meats, and other groceries, the percentage of spoilage for each class can be readily determined, as well as the percentage of total spoilage.

It is valuable to know the percentage of spoilage, since the percentage of mark-up can be more intelligently arrived at after an examination of these records. It is believed that in the majority of cases the percentage of loss through spoilage of fresh fruits and vegetables will be found to be less than is generally supposed. When this is true it becomes possible to reduce the prices on these articles, which in turn will tend to increase sales, and again reduce the loss through spoilage.

Form 5, page 52, headed "Stock Control Adjustment—D," can be used in connection with chain-store organizations or department stores where merchandise is often transferred from one branch to another without a cash payment being made. Obviously, the entire retail value of the transfer should be credited to the merchandise account; therefore, it is necessary only to multiply the number of articles by the selling price per article to obtain this charge. Such a form is needed, because under the ordinary chain-store management no provision is made for adjusting the retail value of the purchases, which must be done in order that each branch may keep its accounts straight.

After the stock-control data are assembled on the special forms as described, they should be reduced to a single statement, somewhat similar to the ordinary operating statement used by many concerns. Form 6, page 52, is a convenient form for this purpose, and can be used to great advantage in bringing out the information obtained in such a way as to make it easily understood. All figures are at the retail selling price. To the opening inventory should be added the net purchases (purchases less transfers), and to the sum should be added total mark-ups. The total will be the gross retail value of the

goods handled. All of the mark-downs should then be added together and subtracted from the gross retail value of the goods handled, the result being the net retail value of the goods handled. The closing inventory should then be subtracted from the net retail value of the goods handled, leaving the net retail value of the goods sold. The net sales are subtracted from this latter figure, leaving the "shrinkage" which represents that loss caused by evaporation, overweight, waste, net losses, if any, from cashier's errors, and petty thievery. So far as can be determined, the first four causes would represent about 1 per cent of the sales in the average store, the remainder resulting from petty thievery.

SUMMARY OF INVESTIGATIONS.

Self-service stores owe their existence to the fact that by eliminating a large part of the salary expense as compared with ordinary service stores the cost of operation can be reduced under favorable conditions, making it possible to sell goods of a given quality at lower prices.

Where economic conditions justify the existence of a self-service store, its advantages over ordinary service stores are:

- Relatively low operating expense.
- Smaller investment in proportion to size of business.
- Greater ease of filling employment needs.
- Greater satisfaction to the average customer.
- Possibility of educating customers through display.

The disadvantages of self-service are:

It is not applicable to all consumers but only to those willing to dispense with certain service for the sake of lower prices. Certain goods can not be "pushed" as when salesmen are employed.

The possibilities of thievery are greater, though the investigations of the Bureau of Markets indicate that thievery is not responsible for any considerable losses.

The important general considerations in the establishment and operation of self-service stores are:

- Proper location.
- Convenient arrangement of the store and display of goods.
- Intelligent buying, grading, and pricing.

Self-service may be satisfactorily applied to the retailing of nearly all perishable farm products except fresh meats, but modifications of the usual methods are necessary in the cases of some such products.

Careful accounting is necessary in operation of a store under self-service. This is true not only because of the methods of merchandising peculiar to self-service, but also because self-service usually

implies operation on a very narrow margin of profit, and where margins are narrow under any system it is important that managers be able to follow costs of operations, volume of business, and rapidity of turnover very closely.

Data, as well as general ideas as to the practicability of self-service, have been gathered from numerous self-service stores located in nearly every section of the country. Some of these stores have been very successful and have applied the principles of self-service to their business intelligently, while others are operating on almost the same basis as when on the service plan, except for a mere changing of the physical arrangement of the stores. Some operators who tried self-service have gone back to the service plan, asserting that self-service was not a success. It was usually found that in those cases the results of the operation showed a lack of knowledge of the fundamentals of self-service. Some failures were due to the poor location of the stores, the operators believing self-service could be made a success in ordinary "neighborhood" store locations. On the whole, it was found that self-service in the distribution of food products is operating successfully wherever the principles of self-service have been intelligently applied, and that where the operations are in the hands of particularly well-qualified operators the success is marked.

Form 1.

OPERATING STATEMENT.

	Per cent.
SALES (net) -----	100
Inventory at beginning -----	-----
Purchases -----	-----
Inward transportation -----	-----
Costs of goods handled -----	-----
Inventory at end -----	-----
COST OF GOODS SOLD -----	-----
GROSS PROFIT -----	-----
Management expense -----	-----
Rent -----	-----
Interest -----	-----
Insurance and taxes -----	-----
Heat, light, and power -----	-----
Repairs -----	-----
Depreciation -----	-----
Wages -----	-----
Advertising -----	-----
Ice and cold storage -----	-----
Wrapping -----	-----
Miscellaneous -----	-----
TOTAL EXPENSE -----	-----
NET OPERATING PROFIT OR LOSS -----	-----

Form 2.

STOCK CONTROL ADJUSTMENT—A.

[For price fluctuation.]

[illegible]

Totals	.....
Subtract	.....
Post difference	.....

Form 3.

STOCK CONTROL ADJUSTMENT—B.

[For special sale mark downs.]

[illegible]

Form 4.

STOCK CONTROL ADJUSTMENT—C.

[For mark downs because of spoilage.]

Class of goods

Article.			Price.		Inventory.	Mark downs.	Credit stock control.
Date.	Description.	Unit.	Old.	New.			
	Total.....						

Form 5.

STOCK CONTROL ADJUSTMENT—D.

[Transfers.]

Article.			Price.	Inventory.	Credit stock control.
Date.	Description.	Unit.			
	Total.....				

Form 6.

STOCK CONTROL SUMMARY.

Per cent.

Opening inventory_____

Purchases _____

Less transfers_____

Net purchases _____

Add mark-ups

GROSS RETAIL VALUE OF GOODS HANDLED-----

Less :

Regular mark-downs_____

Advertising mark-downs-----

Spoilage mark-downs.....

Total mark-downs

NET RETAIL VALUE OF GOODS HANDLED_____

CLOSING INVENTORY.....

RETAIL VALUE OF GOODS SOLD-----

LESS NET SALES..... 100

"SHRINKAGE"

ADDITIONAL COPIES

OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.

AT

10 CENTS PER COPY

V



UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 1045

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.



March 18, 1922

THE SUNFLOWER AS A SILAGE CROP.

By H. N. VINALL, *Agronomist, Office of Forage-Crop Investigations.*

CONTENTS.

	Page.		Page.
Early history of the sunflower-----	1	Yields of silage-----	17
Present distribution-----	2	Feeding value of sunflower silage---	20
Cultivation in the United States----	2	Composition and digestibility---	20
Areas suited to the production		Palatability-----	21
of sunflowers-----	4	Color, texture, and odor-----	23
Value of sunflowers in the semi-		Acidity of the silage-----	23
arid regions-----	5	Results with dairy cattle-----	23
Soil relations and effect on the		Feeding tests with beef cattle---	26
following crop-----	7	Use of sunflower silage in feed-	
Varieties-----	7	ing sheep-----	27
Growing sunflowers for silage-----	9	Feeding sunflower silage to	
Date of seeding-----	10	hogs-----	29
Method and rate of seeding-----	10	Sunflowers as a soiling crop-----	29
Cultivation and irrigation-----	11	Diseases of sunflowers-----	30
Harvesting methods-----	12	Insects attacking sunflowers-----	31
Time to cut sunflowers-----	13	Literature cited-----	31
Filling the silo-----	15		

EARLY HISTORY OF THE SUNFLOWER.

The common sunflower (*Helianthus annuus*) is generally recognized as native of North America, although its natural range of distribution extends southward to Peru. It was one of the food plants of the American Indians (14, p. 419)¹, the seeds being eaten raw or pounded up with other seeds, then made into flat cakes and dried in the sun. The sunflower was grown as early as 1597 in the gardens at Madrid, Spain. The Spaniards probably obtained the seed from Peru, since it was given the name "Peruvian sunflower" by De Lobel, a Flemish botanist, who published a description of the sunflower in 1576. Champlain in 1615 found the Indians in the vicinity of Georgian Bay cultivating the sunflower. The oil which they obtained from the seeds was used on their hair.

¹ The serial numbers (italic) in parentheses refer to "Literature cited" at the end of this bulletin.

The sunflower under cultivation has been widely used as an ornamental, and its seeds are valued as a feed for birds and poultry. In addition, the seeds are used as human food, and when pressed cold produce a fairly good table oil. The resulting seed cake, after the oil has been expressed, is used as a concentrate in feeding cattle and horses. The above-mentioned uses are largely responsible for the widespread distribution of the sunflower.

PRESENT DISTRIBUTION.

The sunflower plant is grown throughout North America, from the southern Provinces of Canada to the Canal Zone. It is to be found also in most parts of South America, but more especially along the west coast from Colombia to Chile. In Australia, New Zealand, South Africa, Egypt, the Mediterranean region of Europe, India, and China the sunflower is grown to a limited extent. It has reached its highest development and its greatest usefulness in Russia, where several important varieties have been developed. It is grown extensively there for its seeds and the oil therefrom, both being consumed as food, and the stalks are utilized as fuel by the peasants.² Next to Russia, Hungary was perhaps the largest producer of sunflowers. There were many mills in that country which were equipped especially for extracting the oil from sunflower seeds, and the oil content of the Hungarian seed was higher on the average than that of seed grown in Russia.³

CULTIVATION IN THE UNITED STATES.

Although the sunflower is a native of the United States and was cultivated by the Indians, early settlers seem to have made little use of it as a crop plant. Most of the sunflowers grown in early days were harvested for seed, but insects, such as cutworms, and also those which live on the seeds, often made the crop an unprofitable one. The United States Department of Agriculture investigated the production of sunflowers in the United States and published the results in 1901 as Bulletin 60 of the Division of Chemistry.

At that time there were no mills producing sunflower oil, and the crop was being utilized largely as feed for cage birds and poultry, the seed only being harvested. In 1895 and 1896 large areas of sunflowers were grown in southern Indiana near Madison. Accord-

² Statistics published in the New York Drug Reporter in 1883 claimed a total production of 228,000,000 pounds of seed in Russia from an area of 216,000 acres, mostly in Kielce, Podolia, and the district of Brutch in Veronez.

³ A good summary of the information regarding the production of sunflower oil and seed cake in Russia and Hungary is to be found in the articles of Richard Windisch in *Landw. Vers. Stat.*, Bd. 57, p. 305-316, and Dr. Th. Kosutany in the same publication, Bd. 43, p. 253-269.

ing to the United States Department of Agriculture Market Reporter of February 5, 1921, there are now three important seed-producing areas in the United States. These are southeastern Missouri, southern Illinois, and the San Joaquin Valley of California. The 1920 seed crop in these three areas was estimated at 9,850,000 pounds.

The New York Agricultural Experiment Station (Geneva) reported some results with sunflowers in 1883, the Vermont station in 1893, and the Maine station in 1895 and 1896. The Canadian Experimental Farms Report for 1893 also discussed the culture of sunflowers in Ontario and other southern Provinces. The last-mentioned work was devoted mainly to studying the value of the silage mixture originated by Prof. James W. Robertson, of Ottawa, Canada, and designed to produce a silage of such composition that the quantity of grain needed in the ration could be reduced. Corn and some legumes, such as the horse bean or soy bean, were grown together in the field, and when ready for the silo the crop from 2 acres of this mixture was put in the silo with the sunflower heads from half an acre. If it was found desirable to grow the legumes and corn in separate fields; then the mixture was made up by combining the crops as follows: One-fourth acre of sunflower heads, one-half acre of horse beans, soy beans, or some other legume, and 1 acre of corn.

Because of the high protein content of the legume and the high fat content of the sunflower seed, this silage mixture possessed a high feeding value. It was claimed that the Robertson mixture produced results equal to those of pure corn silage and required 4 pounds less of concentrate, such as grain or meal, with each 50 pounds of silage fed.

In growing sunflowers for tests of the Robertson mixture in the New England States and Canada most of the investigators obtained a larger yield of sunflowers (total crop) than they did of corn. Some of them also recognized the possibility of utilizing the entire plant for silage. Prof. J. N. Bartlett, of the Maine Agricultural Experiment Station, says that "the very large total yield of sunflowers (48,000 pounds per acre in 1896) would give them a high rank among coarse fodder plants for silage material." Notwithstanding the heavy tonnage produced by the sunflowers and this apparent realization of the value of such a crop for silage, none of these stations ever seriously attempted to make use of the whole plant by ensiling. The idea seemed to prevail in the minds of all these investigators that there could be very little food value in the coarse woody stalks of the sunflower.

Tests of the feeding value of the Robertson mixture were made with dairy cows at the Vermont station and also in Canada. Although the quantity of grain fed with the Robertson silage was

less than with the corn silage, the cows produced approximately equal quantities of milk and butter. The Canadian authorities reported that the butter made from the sunflower mixture had a richer flavor and higher color than that from corn silage. Instructions were issued to Canadian farmers regarding the growing and utilization of sunflowers in the Robertson silage mixture, and it received considerable attention for a few years. The practice of making silage in this way did not become established in American agriculture, however, and little has been heard about it during the past 10 years.

Outside of the experiments carried out in Maine, Vermont, and New York, there has been but little investigation of the value of sunflowers in the United States until recently, although desultory trials of the crop have been reported by New Hampshire, Nebraska, Colorado, and a few other States. In 1915 the Montana Agricultural Experiment Station grew a small acreage of sunflowers under irrigation at Bozeman. The results were so satisfactory that the plantings were enlarged in 1916, and the crop after being ensiled was fed to dairy cattle. This preliminary test, described in Bulletin 118 of the Montana Agricultural Experiment Station, demonstrated the high feeding value of sunflower silage and resulted in a widespread interest in the crop. Since the publication of this report numerous other States, as well as the United States Department of Agriculture, have experimented with sunflowers rather extensively as a silage crop.

AREAS SUITED TO THE PRODUCTION OF SUNFLOWERS.

Sunflowers are widely distributed in nature and can be grown successfully in nearly every part of the United States. Their value in any region, however, depends more on the measure of success attained in the production of other crops than on their own adaptation to the local climatic conditions. Thus, it is doubtful whether sunflowers will ever be popular for a silage in the central and southern Great Plains, because the sorghums do so well there, nor in the corn belt, because corn so well fills the need for a silage crop. In the Southeastern States corn, sorghum, Japanese cane, pearl millet, and other silage crops are well adapted to the climatic conditions, and sunflowers are not likely to find a place.

In the extreme northern part of the United States or at high altitudes in the Western States where the temperatures during the growing season are relatively low, corn, sorghum, and other crops do not produce heavy yields for silage. In such situations the sunflower is recognized as an extremely valuable silage crop, and the acreage devoted to its production is increasing rapidly. Now that feeding experiments have demonstrated the high quality of this silage, it is probable that the sunflower will be grown quite widely in the New

England States, northern New York, Michigan, Wisconsin, and Minnesota, in North Dakota, Montana, Washington, and Oregon, and also in some of the high valleys of the Rocky Mountain region, such as the San Luis Valley of Colorado.

Sunflowers have been found much more resistant to frost than corn. An observer in Michigan claims that they will "push back the frost line three weeks" in that State. A correspondent in New York writes that his sunflowers were green in the fall two weeks after corn had been killed by frost. These observations explain why sunflowers succeed in the high altitudes of Colorado and other Western States where frosts often occur during the growing season.



FIG. 1.—A field in Ellis County, Kans., overrun by wild sunflowers during the wet season of 1915.

VALUE OF SUNFLOWERS IN THE SEMIARID REGIONS.

On account of the fact that sunflowers grow wild in western Kansas (fig. 1), Nebraska, South Dakota, and North Dakota, as well as in eastern Montana, Wyoming, and Colorado, it was anticipated that they would be important as a silage crop in dry regions. This has not proved to be the case. The yields at dry-land stations south of the Dakotas have not been large enough to warrant their production under cultivation. Field tests show that the sorghums give much higher yields under such conditions.

At the Fort Hays Experiment Station, Hays, Kans., sunflowers were grown first in 1913. This was an unusually dry year and the plants made a very poor showing. None of them grew over a foot and a half high, and the yield was small. The better varieties of sorghum under the same conditions made a yield of 2 to 2½ tons of

silage per acre. Sunflowers were not grown again at Hays until 1920. The rainfall was fairly abundant that year, and the general crops were good. Sunflowers suffered from rust and insects and again made a very poor showing in comparison with the sorghums.

At Akron, Colo., where the altitude is greater than at Hays, Kans., sunflowers were tested in 1911 and 1912. Only seed yields were obtained in those years, but the growth was good and insects gave little trouble. The estimated total crop was about three-fourths that of the best varieties of forage sorghums.

At Amarillo, Tex., sunflowers were grown in 1911, 1912, and 1913. The first two years the crop was fairly good, but the yield was hardly more than half that of the sorghums. In 1913 the crop was almost entirely destroyed by insects. In the semiarid region of the southern Great Plains the value of sunflowers as a silage crop is sure to be limited by the presence of numerous insects which attack the plant.

The Montana Agricultural Experiment Station made some tests of sunflowers on dry-land farms in 1918 (4, p. 9). The average yield of silage on 13 different farms in eight counties was 10.3 tons per acre. There was no basis for a comparison of this yield of sunflowers with that of corn grown under similar conditions. The conclusion at the Montana station, however, was that considering the low seasonal rainfall the yield obtained was quite satisfactory and "that sunflowers are promising dry-land forage producers." This is perhaps true in Montana, where the temperatures are low during the growing season and sorghum and long-season varieties of corn can not be grown.

Sunflowers were grown for ensilage in 1920 at the United States Sheep Experiment Station near Dubois, Idaho,⁴ at an elevation of 5,700 feet, on the range land of the station by dry-land farming methods. The land is of lava-rock formation, and the area available for cultivation is limited. Although the annual precipitation is about 16 inches, it was so dry in 1920 that wheat on the farmed lands adjacent to the sheep reserve was a total failure. Regardless of this fact, the sunflowers yielded between $4\frac{1}{2}$ and 5 tons of ensilage per acre.

To obtain a maximum crop of sunflowers by dry-land farming Mr. McWhorter advises the following procedure:

(1) Summer fallow. Plow the land the previous spring. Keep the plowed area free from weeds and covered by a dust mulch throughout the summer and fall.

⁴The work at this station is conducted by the Bureau of Animal Industry of the United States Department of Agriculture. Mr. V. O. McWhorter, who is in immediate charge of the station, has kindly furnished, through Mr. D. A. Spencer, senior animal husbandman in sheep and goat investigations, a preliminary statement of the results obtained with sunflowers. All future statements in this bulletin regarding work at the Dubois station are based on this report.

(2) Plant early. Plant the sunflower seed in a well-stirred yet firm bed as early in the spring as the condition of the ground will permit. Although heavy freezing is injurious to the young plants, light frosts do not hurt sunflowers.

(3) Harrow. When the young plants begin to appear, use a spike-tooth harrow adjusted for shallow cultivation.

(4) Thin the plants in the rows. Make the rows as far apart as corn is usually planted. When the shoots are well started, thin to one or two plants to the hill, 30 to 36 inches apart in the row.

(5) Cultivate thoroughly. Cultivate lightly with an ordinary corn cultivator as often as needed.

SOIL RELATIONS AND EFFECT ON THE FOLLOWING CROP.

No very definite information regarding the behavior of sunflowers on different soil types is available. The best yields are obtained on rich clay loams well supplied with humus, but the crop has been grown successfully on sandy soil in northern Michigan and on poor clay soils in West Virginia. Sunflowers will thrive on any soil which will produce a good crop of corn.

It was observed on the fields of the Washington Agricultural Experiment Station (17, p. 11) in 1919 and 1920 that the outside rows of the sunflower plats next to the corn made a more vigorous growth than rows in the centers of the plats. Conversely, the corn rows next the sunflower plats were less vigorous than the rows in the centers of the plats. This seemed to indicate an ability on the part of the sunflowers to obtain a greater portion of the plant food and soil moisture than corn when grown in competition with that crop. The plats which produced corn and sunflowers in 1919 were seeded to wheat in 1920. The average yield of wheat on the corn plats was 33.78 bushels and on the sunflower plats 28.36 bushels per acre. These results at the Washington station indicate that sunflowers are more exhaustive of the plant food and moisture in the soil than corn. This can be accounted for in most part by the larger tonnage obtained from the sunflowers. More experiments of this kind are necessary before definite conclusions are possible.

VARIETIES.

The principal variety of the sunflower now grown in the United States for silage purposes is the Mammoth Russian. This variety usually has a single stalk with comparatively few branches and one head 6 to 12 inches in diameter. The seeds are approximately half an inch long and one-fourth to five-sixteenths of an inch wide. They vary in color from almost pure white to black; most of them, however, are white with longitudinal streaks or bands of gray or black. The Mammoth Russian is a vigorous heavy-stemmed variety with large leaves and produces heavy crops of seed.

Wiley (19) says that three principal varieties are grown in Russia: One with large white seeds, valued for its high oil production; one with smaller black seeds, which are sweeter and regarded as best for eating; and the intermediate form with striped seeds, used both for food and for oil production.

The common wild sunflower of the United States often has a much-branched stalk (fig. 2), with numerous heads 3 to 4 inches in diameter. The yield of silage produced by this plant when grown on rich soil under cultivation is usually somewhat less than that obtained from the Mammoth Russian variety under the same conditions. At Red-



FIG. 2.—Two rows on the left, Mammoth Russian sunflowers; two rows on the right, wild sunflowers, Redfield, S. Dak. Both varieties were seeded on April 28, 1920, and photographed in August.

field, S. Dak., in 1920 the total crop, green weight, of the wild sunflower was 13.9 tons per acre, while the Mammoth Russian in an adjoining plat yielded 15.2 tons per acre.

There has been no extensive development of sunflower varieties in the United States. The seed trade has advertised at times six or eight supposedly different varieties, but many of these are only slightly differing strains or selections of the same variety. Probably the most extensive varietal trial made was that of the Department of Agriculture of Ontario, Canada. In 1894 and 1895 seven varieties were under test at Ottawa.⁵ These varieties, *Helianthus globosus*,

⁵ Ann. Rpt., Dept. of Agr., Ontario, v. I, p. 261. 1895.

Texas Silver Queen, Black Giant, Mammoth Russian Giant, Common, Double California, and Silver and Gold, yielded in the order named 10.63 to 4.87 tons per acre except the last-named variety, which was tested only in 1895 and produced in that year at the rate of 11.39 tons per acre. These same varieties were continued under test in 1896, but a poor stand was obtained, and the year's results therefore were not included in the averages. The seed for these tests ordinarily was purchased from seed houses in the United States.

Notwithstanding the fact that some of these varieties made a very good showing, most of them were discarded and only three, the Black Giant, Mammoth Russian, and White Beauty, were grown in subsequent years. In the report for 1897 this action is explained as follows: "As some of these varieties, however, did not give satisfactory results nearly all of them were dropped from the list." Since a number of the seven varieties, such as the *Helianthus globosus* and Texas Silver Queen, made larger yields than any of the varieties contained in the tests, it is evident that some consideration other than the yield must have been responsible for the action of the Ontario officials in discontinuing the tests of those varieties. The average yield, green weight, of the varieties included in the test for 16 years was Black Giant, 22.3; Mammoth Russian, 17.8; and White Beauty, 16.5 tons per acre.

The Michigan Agricultural Experiment Station conducted a variety test of sunflowers in 1918, but this test developed quite largely into a question of rust resistance.⁶ The Mantica, developed by Luther Burbank; the Kaeurpher, from South America; the Mammoth Russian; and the Double Mixed were tested. Of these varieties the Kaeurpher was the only one which proved rust resistant. More experimental work with varieties will have to be conducted before a decision can be reached as to the best variety for silage purposes.

GROWING SUNFLOWERS FOR SILAGE.

Only within the past decade have sunflowers been grown extensively in the United States for silage. In growing the crop for this purpose it is, of course, important to use cultural methods that will yield the largest tonnage. To attain this result it is usually necessary to plant more thickly than where a seed crop is the object.

The same treatment of the soil that prepares the surface for corn planting will answer for sunflowers. The ground is usually plowed in the spring and worked down with a spike-tooth harrow, or if fall

⁶ Mich. Agr. Exp. Sta. Quar. Bul., v. 3, no. 3, Feb., 1920, p. 128-129.

plowed it can be put into condition for planting by disking in the early spring.

DATE OF SEEDING.

The best date to plant sunflowers of course varies with the locality. In the Upper Peninsula of Michigan at the Chatham Experiment Station (15, p. 50) it was found that seeding May 26 gave a larger yield and a better quality of silage than on June 2 and 9.

At the West Virginia Agricultural Experiment Station, Morgantown, W. Va. (3), June 5 proved a satisfactory date for seeding. At the Montana Agricultural Experiment Station at Bozeman (4, p. 9), seedings were made each week in 1918 from April 29 to June 10. The largest yields were obtained from seed sown on the earliest date. Seeded on April 29 the plants appeared above ground in 12 days and the yield was 39.7 tons of silage per acre; sown one month later, May 29, the young plants were up in 5 days and the yield was 36.8 tons, green weight, per acre; sown June 10 the plants were up in 3 days and the yield was 22 tons, green weight, per acre. The seedings made between April 29 and May 29 gave lower yields than the May 29 seeding, although they were higher than the yield for June 10. The recommendations of the Montana station, based on the rather inconsistent results obtained in 1918, are to defer seeding in the higher altitudes until the ground is warm and in good condition.

On the Scottsbluff Reclamation Project Experiment Farm, Mitchell, Nebr., good results were obtained from seedings made on May 24 (8, p. 25). At the experiment stations at Akron, Colo., Hays, Kans., and Amarillo, Tex., seedings have been made from May 15 to June 15.

These date-of-seeding tests indicate that sunflowers may be sown at the same time the farmer plants corn.

METHOD AND RATE OF SEEDING.

In early experiments with sunflowers in Maine, Vermont, New York, and in Canada the seedings were usually made with a corn planter in rows 3 feet apart. It was advised that not more than three or four seeds be dropped in each foot of row space. In some cases the plats were thinned so that the plants stood 8 to 12 inches apart in the row.

In later experiments carried on in West Virginia, Michigan, Montana, Nebraska, and other western points the ordinary grain drill has been found better suited for seeding sunflowers than the corn planter. The required space between the rows is accomplished by stopping up a certain number of holes or feeds in the drill box. In general, the largest yields and the best quality of silage have been

obtained when the rows were 24 to 30 inches apart. For such seedlings 6 to 8 pounds of seed per acre are required.

At the Michigan station (15, p. 50) sunflowers were seeded in rows 6, 12, 18, 24, 30, 36, and 42 inches apart. The best yields were obtained from the 30-inch rows. At Huntley, Mont. (7, p. 12-14), sunflowers drilled in rows 20 inches apart produced 37.6 tons silage per acre; in rows 30 inches apart, 32.9 tons; and in rows 40 inches apart, 31.0 tons per acre. At Bozeman, Mont. (4, p. 6, 7), sunflowers were seeded in rows 8, 20, 24, 30, 36, and 42 inches apart, the quantity of seed varying from 30 to 4 pounds per acre, according to the width of row. The average yield of silage for the two years 1917 and 1918 was highest in the 36-inch rows, 44.1 tons per acre. The 8-inch rows were second, with a yield of 39.8 tons per acre, and the 30-inch rows ranked third, with 33.6 tons of silage per acre.

Other experiments designed to determine the comparative value of planting in hills were carried out at Huntley and Bozeman, Mont. Sunflowers were planted in hills 6 and 12 inches apart in all the different row widths at Huntley and in hills 4, 8, and 12 inches apart in each of the row widths, 24, 30, and 36 inches, at Bozeman. At Huntley the average silage yield of the drilled plats in the three different row widths was 33.8 tons per acre; for the 6-inch hills, 30.6 tons; and for the 12-inch hills, 30.2 tons per acre. At Bozeman (4, p. 7, 8), although the highest single yield reported, 44.1 tons per acre, was from drilled rows 36 inches apart and the lowest, 18.2 tons per acre, from hills 42 inches apart each way, the averages showed larger yields for the plats planted in hills than for those drilled. The actual difference in yield, however, was small. The average for the three row widths in drilled seedings was 34.8 tons of silage per acre; for the rows planted in hills 4 inches apart, 36.2 tons; in hills 8 inches apart, 35.3 tons; and in hills 12 inches apart, 35.7 tons per acre.

The results at the two stations are contradictory, and further work will be necessary to clear up the value of these two methods. It is somewhat easier to drill the seed in the row than to plant in hills at the distances obtaining in these experiments. It is evident from the experiments already completed that where the hills are separated by a considerable distance, as they are in checkrowed corn, the yields are appreciably smaller than in drilled rows.

CULTIVATION AND IRRIGATION.

If a crust forms on the soil before the plants come through or immediately afterwards, a light harrowing will help to obtain a good stand. After the plants are 4 to 8 inches tall the ordinary corn cultivator may be used, just as with corn. In some cases, like

that reported by the West Virginia Agricultural Experiment Station, the growth is so rapid that only one cultivation is necessary, after which the plants shade the ground so thoroughly that weeds can not grow. Ordinarily, however, two or three cultivations are necessary.

At the Huntley, Mont., experiment farm three irrigations were given sunflowers seeded May 21, 1918, water being applied uniformly to the field on July 9, August 2, and August 18 (7, p. 12-14). In 1917 five irrigations were given. The frequency and character of cultivations and irrigations will necessarily have to be determined to a large degree by the grower. The large growth produced and the consequent high rate of water loss in dry regions means a correspondingly high water requirement.



FIG. 3.—Harvesting sunflowers for silage with a row binder equipped with an elevator to carry the bundles directly into a header barge.

HARVESTING METHODS.

The most efficient method of harvesting sunflowers for silage where the crop has not lodged badly and the stalks are not too large in diameter is with the ordinary corn or row binder. This machine ties the stalks in bundles, making it easier to load and transport them to the silage cutter. Everything possible should be done to reduce to a minimum the handwork required. Farm laborers dislike to handle sunflowers on account of the resinous exudation on the stems, especially where they are cut or bruised, and also because of the rough surfaces of the stems and leaves.

At the Dubois (Idaho) sheep station an elevator was devised to carry the bundles directly from the row binder into a header barge. (Fig. 3.) Sunflower plants 8 to 9 feet tall were handled by the

binder with this loader attachment. A machine thus equipped reduces the hand labor to a minimum.

Where the crop has lodged or a row binder is not available, the sunflowers may be harvested with a sled to which knives have been attached or with an ordinary corn knife (fig. 4). Either of these methods of harvesting should be used only in an emergency. Many farmers have reported that it is necessary to pay farm laborers increased wages when such work is in progress.

TIME TO CUT SUNFLOWERS.

There has not been a sufficient number of experiments to determine definitely the best stage of maturity at which to cut sunflowers for silage. The Montana Agricultural Experiment Station (4, p. 20-21) conducted feeding experiments with two lots of silage; one from



FIG. 4.—Cutting sunflowers for silage by hand. This method should be used only when the crop has been tangled by the wind or is too heavy for a row binder to handle.

sunflowers cut early, when only 30 per cent of the plants were in bloom, and the other lot from sunflowers cut later, when 90 per cent of the plants were blooming. Unfortunately, no figures showing the comparative yields of silage for the two methods are given, and the results of the feeding test are not conclusive. The dairy cows fed on the early-cut silage produced slightly less milk and butter fat, but gained more in weight than those fed on the late-cut silage. However, the cows fed the early-cut silage consumed a little more silage and grain than those fed late-cut silage. The evidence, therefore, points to a slight advantage in the late cutting. The investigators conclude that sunflowers should not be cut for silage until 50 to 60 per cent of the plants are in bloom, not only because of the

apparent higher feeding value of the late-cut silage, but because there is also a greater loss of juices when the plants are harvested at an earlier stage.

There has been trouble in several cases caused by the loss of juice from sunflower silage. At the field station of the United States Department of Agriculture, at Ardmore, S. Dak., 57 tons of sunflowers were cut about August 25, 1920, and stored in a wooden silo 12 feet in diameter. The silo was filled to a depth of 24 feet. During the first month it was estimated that several thousand gallons of juice escaped through the cracks and around the doors. This loss of juice was accompanied by a shrinkage of 40 per cent in bulk. Other reports of the loss of juice from sunflower silage have been received. In several of these instances, however, the sunflowers were cut when one-third or less of the plants were in bloom. Such sunflowers might be expected to produce "sappy" silage.

At the Huntley, Mont., experiment farm in 1918 the sunflowers were harvested for silage when "on about one-half the plants seed heads were formed, and some were so far advanced that the seeds were in the hard dough stage. The remainder of the plants were in various stages of blooming." The silage made from this crop was not very readily eaten by the cows. This was seemingly due to the fact that much of the silage remained hard and woody in the silo. The report states that apparently the sunflowers were allowed to become too mature before harvesting to make the most palatable silage.

At the West Virginia station (3, p. 2, 6, and 7) the sunflowers were cut for silage "when the majority of the seeds of the plants were in the light dough stage." No difficulty was experienced either in harvesting or ensiling the sunflowers at this stage of maturity, and none of the silage was refused or not eaten by any cow during the entire test. "After a few days the cows ate the sunflower silage practically as well as corn silage."

The composition of sunflower plants at different stages of maturity is shown by a series of analyses made at the West Virginia Agricultural Experiment Station in 1919 (3, p. 3). Additional work of this nature has also been done by Shaw and Wright (18) of the United States Department of Agriculture. They found that sunflower plants 3 feet high contained 84.87 per cent of moisture; 6 feet high, 86.02 per cent; in first flower, 84.09 per cent; with rays ready to fall, 83.9 per cent; with rays dry and partly fallen, 75.58 per cent; with rays all fallen, 74.37 per cent; and when the seeds were hard and mature, 69.68 per cent. This decrease in the percentage of moisture as the plant grows older conforms more nearly with the conditions existing in other plants than do the continuously high moisture percentages found at the West Virginia station. The sun-

flowers used in the experiments of Shaw and Wright were grown at Beltsville, Md. Corn grown in the same field had 68.69 per cent of moisture at the time it was sufficiently mature to put in the silo.

The average amount of moisture in sunflower silage, as shown in Table 2 of this bulletin, is 77.8 per cent. This is less than that of silage made from immature corn and only 6.9 per cent greater than the percentage of moisture in silage made from mature corn.

The results of Shaw and Wright also indicate that the percentage of proteids in the plant steadily declines as it matures. The sugar content also decreases. The greatest difference, however, is in the starch content. In corn at the time it is ready for the silo 24 per cent of the dry matter of the plant is starch; in the sunflower less than 1 per cent is starch. The starch and sugars combined constitute 37 per cent of the total dry matter of the corn plant and only 11.2 per cent of the sunflower plant.

Shaw and Wright conclude from their chemical data that the best time to cut sunflowers for silage is when the ray flowers have become

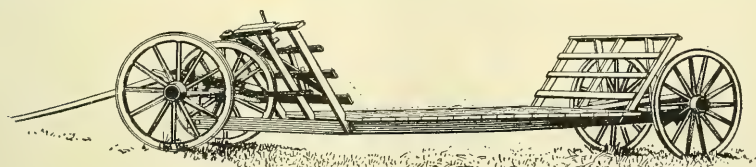


FIG. 5.—Low flat-topped wagons save much hand labor in loading sunflowers to be hauled to a silo.

dry and are partly fallen. Judging from the limited information now available regarding the use of sunflowers for silage, it is best to cut the crop before the seeds have reached the hard dough stage. Most writers advise harvesting sunflowers for silage when only 50 to 60 per cent of the plants are in bloom. Decision regarding the best stage of maturity at which to cut will depend somewhat on location, especially as to rainfall and atmospheric humidity. In dry climates the plants can be harvested at an earlier stage of maturity than in humid climates.

FILLING THE SILO.

For hauling the sunflowers to the silo low flat-topped wagons, such as are used for hauling corn silage, are desirable (fig. 5). The ordinary silage cutter can be used for sunflowers, but one with a wide throat is desirable in order to accommodate the large heads. The knives should be adjusted to a quarter-inch cut and bolted on the cutter securely, because the stalks of the sunflower are somewhat hard and woody.

Little trouble will be experienced in cutting sunflowers if the plants are fed into the silage cutter tops first. Sunflower silage packs more easily than corn silage. If harvesting has been delayed for any reason until the sunflowers are older and somewhat dry it will be necessary to add water along with the silage. With such silage more care is required to tramp it down thoroughly. Sunflowers usually produce an inferior quality of silage if harvested later than the blooming stage.

A word of caution is necessary in regard to the strength of the silo used in storing sunflower silage. Those who have had experience in ensiling sunflowers find that they pack much more closely

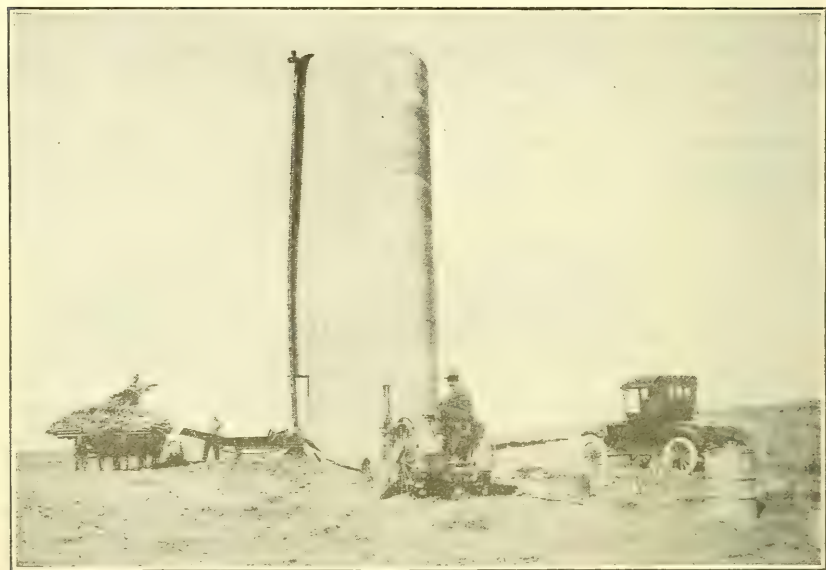


FIG. 6.—Filling with sunflowers the 200-ton concrete silo on the United States Sheep Experiment Station near Dubois, Idaho.

in the silo than corn. This close packing, of course, means heavier silage and in large silos results in much greater pressure on the walls of the silo. George M. Rommel, formerly Chief of the Animal Husbandry Division, Bureau of Animal Industry, United States Department of Agriculture, is authority for the statement that a silo constructed to hold 200 tons of corn silage will hold nearly 300 tons of sunflower silage.

Rommel says that a new monolithic concrete silo 14 feet in diameter and 50 feet high was built with 6-inch walls and the ordinary quantity of metal reinforcement on the United States Sheep Experiment Station near Dubois, Idaho, in 1920. (Fig. 6.) This silo, while it was being filled with sunflowers that fall, began to crack from the pressure when it was little more than half full. Fill-

ing had to be discontinued and the silo reinforced with steel bands in order to save it. Rommel found on inquiry that many farmers in the Northwest who had filled their silos with sunflowers had had similar experiences.

One of the hoops on a wooden silo at Huntley, Mont., burst while the silo was being filled with sunflowers, making it necessary to reinforce the silo with an iron band. Inquiries addressed to the Montana, Washington, and Oregon agricultural experiment stations, however, elicited the information that no trouble of this kind had been encountered at those stations, and none had been reported to them by farmers.

Nothing definite is yet known about the comparative pressure exerted on the silo walls by corn and sunflower silage. No advice can be given, therefore, as to the additional reinforcement necessary for silos intended to hold sunflowers. Care should be used, however, in building such a silo, and the ordinary silo should be watched closely while it is being filled with sunflowers and until the settling process is completed. If it shows signs of cracking, serious trouble can be averted by reinforcing it with iron bands.

YIELDS OF SILAGE.

The yields of sunflower silage have been consistently larger than those of corn or other silage crops in the northern part of the United States and the higher altitudes of the Rocky Mountain region, where the temperatures are low during the summer season. The results of the more important of these comparative tests are listed in Table 1.

Where the yields are recorded for different rates of seeding, as at Huntley, Mont., that given in the table was obtained from drilled rows 30 to 36 inches apart, because drilling in rows is the more common method of culture and the one which no doubt will be most widely used by farmers. This method has not always given the largest yield, as will be seen by reference to the paragraph on the rate and method of seeding. The average yields of sunflowers, corn, and sorgo are not given, because these three crops were not all grown at a sufficient number of the stations to make the averages comparable. In the first series of yields from Guelph, Ontario, the Mammoth Russian variety of sunflowers, which made the second highest yield among the sunflower varieties tested, is compared with the second highest yielding varieties of corn and sorgo. In the second series the Black Giant variety of sunflower is compared with Wisconsin No. 7 corn and Orange sorgo. These varieties made the highest silage yields, respectively, of each of the crops under test.

TABLE 1.—*Comparison of the yields per acre of sunflower, corn, and sorgo silage.*

[Yields obtained under irrigation are given in italic figures; those not in italic were obtained without irrigation.]

Locality.	Year.	Yields per acre (tons).		
		Sun-flowers.	Corn.	Sorgo (cane).
Pullman, Wash.	1919 and 1920.	<i>a</i> 11.6	<i>a</i> 6.0	.....
Umatilla, Oreg.	1918.	<i>a</i> 28.4	<i>a</i> 10.8	.....
Moro, Oreg.	1917.	1.6	.....	.....
Wallowa County, Oreg.	1920.	22.5	.....	.....
Do.	1920.	7.0	.....	.....
Reno, Nev.	1917.	25.1	<i>a</i> 14.2	.....
Do.	1918.	19.9	13.0	.....
Moscow, Idaho.	1919.	13.0	10.0	.....
Bozeman, Mont.	1915.	36.8	.....	.....
Do.	1916.	31.1	.....	.....
Do.	1917 and 1918.	<i>a</i> 35.6	.....	.....
Havre, Mont.	1920.	3.3	2.6	.....
Huntley, Mont.	1917.	19.4	10.5	.....
Do.	1918.	32.9	9.3	.....
Do.	1919.	27.8	10.4	.....
Laramie, Wyo.	1919.	12.0	.....	.....
State College, N. Mex.	1919.	20.0	15.0	20.0
Tucumcari, N. Mex.	1920.	4.3	3.9	.....
Dickinson, N. Dak.	1918.	10.5	6.1	.....
Do.	1919.	3.0	2.0	.....
Do.	1920.	8.3	4.0	.....
Newell, S. Dak.	1917.	12.6	<i>b</i> 10.4	.....
Do.	1918.	12.8	8.2	<i>c</i> 11.3
Redfield, S. Dak.	1920.	15.2	10.4	15.5
Scottsbluff, Nebr.	1917 to 1919.	<i>a</i> 16.3	<i>a</i> 14.6	.....
St. Paul, Minn.	1919.	10.0	10.0	.....
Duluth, Minn.	1918.	18.3	.....	15.6
Chatham, Mich.	1919.	25.0	.....	.....
Clinton County, Ill.	1919.	15.5	11.0	.....
Morgantown, W. Va.	1919.	18.0	8.5	.....
Cazenovia, N. Y.	1919.	18.0	7.5	.....
Orono, Me.	1895.	24.4	.....	.....
Guelph, Ontario, Canada.	(<i>d</i>)	17.1	15.8	16.7
Do.	(<i>e</i>)	20.3	16.9	17.2
Calgary, Alberta, Canada.	1919.	39.0	14.0	.....

a The yield given is the average for the years specified.

b The corn yields listed are those of the Payne White Dent, the highest yielding variety which matured sufficiently to make good silage. Red Cob corn, a southern variety, made an average yield of 13.15 tons per acre for the two years, but was so immature when harvested that the silage was of very poor quality.

c The Red Amber sorgo was too immature when harvested to make good silage.

d Average yields of Mammoth Russian sunflower and White Cap Yellow Dent corn each for 13 years and Minnesota Amber sorgo 15 years.

e Average yields of Black Giant sunflower and Wisconsin No. 7 corn each for 13 years and Orange sorgo 15 years.

There are other tests of these crops mentioned in agricultural literature, but no definite yields are given. In the Quarterly Bulletin of the Michigan Agricultural College for May, 1920, it states that in 1919 careful estimates of the yields on eight farms in Ogemaw, Grand Traverse, Otsego, and Emmet Counties showed that "on an average sunflowers yielded 20 per cent greater tonnage per acre than the corn grown in the same fields. On the college farm at East Lansing, a 3-acre strip of sunflowers produced a 30 per cent greater tonnage than an equal area of corn adjacent." C. B. Tillson, county agricultural agent of Clinton County, N. Y., writing in the Rural New Yorker, February 21, 1920, says that there were 30 tests of sunflowers in Clinton County in 1919 and that in many instances the sunflowers out-yielded corn from 30 to 35 per cent. He adds that the sunflowers out-

yielded the corn most where the conditions were least favorable for the corn. He believes that sunflowers will be grown most extensively on farms unsuited to the production of silage corn.

The yields shown in Table 1 seem very favorable to sunflowers because the tests were made mainly in those regions where the large-growing varieties of corn suited for silage purposes are not adapted to the climatic conditions. It can be said also that a large part of these yields was obtained under irrigation. (Fig. 7.) Where the crops can not be irrigated and in localities where silage varieties of



FIG. 7.—Sunflowers grown for silage purposes under irrigation on the Scottsbluff Reclamation project, near Mitchell, Nebr., 1917. Yield, 22.9 tons per acre, green weight.

corn mature properly, the comparative yields of corn and sunflowers are much less favorable to the latter.

FEEDING VALUE OF SUNFLOWER SILAGE.⁷

Considering the fact that only a few years have elapsed since an interest in the use of sunflowers for silage was created by the experiments at the Montana Agricultural Experiment Station in 1915, a comparatively large number of feeding experiments have been carried out. Most of these indicate that sunflower silage when properly made is equal to corn silage for milk-production purposes. Sunflower silage has also been fed at the Montana station to beef cattle, breeding ewes, and brood sows with good results.

⁷ Prepared with the advice and cooperation of the Animal Husbandry Division of the Bureau of Animal Industry, United States Department of Agriculture.

COMPOSITION AND DIGESTIBILITY.

The composition of sunflower silage, as shown by chemical analyses, compares very favorably with that of corn and the sorghums. While somewhat lower in carbohydrates or nitrogen-free extract than the corn and sorghums, it is, on the other hand, higher in fat and protein. The analyses made at different places are presented in Table 2.

TABLE 2.—*Comparison of the composition of sunflower, corn, and sorghum silage.*

Kind of silage.	Number of samples.	Constituents (per cent).						Authority.
		Water.	Ash.	Crude protein.	Crude fiber.	Nitrogen-free extract.	Ether extract.	
Sunflower.....	4	78.6	1.6	2.1	6.8	10.4	0.5	Mont. Bul. 131, p. 14. ^a
Do.....	3	78.5	2.4	2.4	5.8	9.8	1.1	Jour. Agr. Res., v. 18, p. 327.
Do.....	1	67.8	3.4	4.3	6.6	16.6	1.3	M. J. Blish, for silage from Ardmore, S. Dak.
Do.....	1	76.2	2.3	1.9	7.5	11.0	1.2	W. Va. Circ. 32, p. 3.
Do.....	3	82.3	3.0	1.9	4.8	7.3	.7	U. S. Dept. Agr., Bu. Chemistry.
Do.....	1	69.8	2.5	3.1	9.1	14.6	.9	U. S. Dept. Agr., Anim. Hus. Div. ^b
Do.....	1	77.9	2.2	1.7	6.4	10.0	1.8	Wash. Bul. 158, p. 11.
Average (weighted).....	14	77.8	2.4	2.2	6.3	10.4	.9	
Corn.....	730	70.9	1.4	2.4	6.9	17.5	.9	Farmers' Bulletin 1240
Corn stover.....	6	80.7	1.8	1.8	5.6	9.5	.6	"Feeding Farm Animals."
Sorghum.....	16	77.6	1.7	1.5	7.1	11.0	1.1	

^a The silage used in these analyses was made from sunflowers harvested when only 5 per cent of the plants were in bloom and therefore without mature seeds.

^b This analysis was made by Dr. M. J. Blish, of the Montana Agricultural Experiment Station. The sunflowers were grown in 1920 by the Animal Husbandry Division on their sheep ranch near Dubois, Idaho.

The percentage of digestible nutrients in sunflower silage has been determined by the Montana Agricultural Experiment Station and the results are given fully in Bulletin 134 of that station (10). The silage used in these experiments was made from sunflowers cut when only 5 per cent of the plants were in bloom. This explains the low percentage of fat (ether extract) shown by the Montana analyses in Table 2. The coefficients of digestibility as determined for this silage were as follows: Crude protein, 59.88; crude fiber, 42.33; nitrogen-free extract, 69.75; and ether extract, 70.63 per cent.

Table 3 shows that the silage made from sunflowers is not equal in digestible nutrients to that made from corn. The amount of digestible crude fiber and nitrogen-free extract combined is higher in corn silage than it is in sunflower silage, but this difference is partly balanced by the higher percentage of digestible fat in the sunflower silage.

TABLE 3.—*Digestible nutrients in 100 pounds of sunflower, corn, and sorghum silage.*

Kind of silage.	Animals used.	Digestible nutrients (pounds).			Nutritive ratio.	Authority.
		Crude protein.	Crude fiber and nitrogen-free extract.	Ether extract.		
Sunflower.....	3 steers..	1.24	10.13	0.37	^a 8.8	Mont. Bul. 134, p. 8.
Do.....	do.....	1.14	10.85	.85	11.2	W. Va. Circ. 32, p. 3. ^b
Do.....	3 cows..	.97	7.72	.91	10.1	Jour. Agr. Res. v. 20, p. 881.
Do.....	3 sheep..	1.10	9.62	.95	10.6	
Do.....	do.....	1.00	^c 8.17	1.45	11.4	Wash. Bul. 158, p. 11.
Do. (average)....		1.09	9.30	.91	10.4	
Corn.....		1.39	17.39	.67	13.5	} Farmers' Bulletin 1240, "Feeding Farm Animals."
Corn stover.....		1.04	10.78	.45	11.8	
Sorghum.....		.87	12.92	.82	16.4	

^a This figure was incorrectly given as 9.8 in Mont. Bul. 134.

^b The coefficients of digestibility for sunflower silage determined in the Montana experiments were used in computing the digestible nutrients of the silage made in West Virginia to show the difference in results when a silage made from more nearly mature plants is considered. It is recognized that this method is subject to criticism, but the results, it is believed, are approximately correct.

^c In Washington Bul. 162, p. 15, this figure is given as 8.29.

PALATABILITY.

There are some differences of opinion regarding the palatability of sunflower silage. Most of the evidence from feeding trials conducted in the United States and Canada leads to the conclusion that even though animals may hesitate at first to eat sunflower silage freely, they soon become accustomed to it and, with the possible exception of corn silage, show no preference between it and other kinds of silage. In a number of instances where adverse reports were made as to the palatability of sunflower silage, it is apparent that the crop was not in the right condition when it was put in the silo. At the Huntley (Mont.) and Scottsbluff (Nebr.) experiment farms the sunflowers were not always cut before the seed had reached the hard dough stage, and some of the silage remained hard and woody in the silo.

It is difficult to determine just why the sunflower silage is so uniformly good at Bozeman, Mont., and so often of poor quality or at least low in palatability at Huntley, in the same State. Chemical analyses of sunflower plants grown at Huntley show a lower sugar content than plants grown at Bozeman. This deficiency in sugar may diminish the fermentation processes necessary to produce good silage. A similar difference in the composition of the plants may explain the difficulties which have been encountered at Scottsbluff, Nebr. Holden (9, p. 26-28), in his report for the years 1918 and 1919, says that while cows ate the sunflower silage in 1917 very well when it was fed for short periods alternating with corn silage, they did

not eat as much of it as of the corn silage. In 1918, when they were fed on sunflower silage continuously for a considerable period, both dairy cows and beef cattle ate the sunflower silage very well at first, but after 10 days or two weeks they would not eat as much. "It seemed the longer they were fed sunflower silage the less they would clean up. The cows also dropped off in their milk flow."

In 1919 Holden added to the sunflower silage about 10 per cent, by weight, of molasses from the sugar factory. Dairy cows, beef cattle, and fattening lambs ate this silage fairly well, but even with the molasses added they did not relish it as well as they did the corn silage.

At the Wisconsin Agricultural Experiment Station the leaves of the sunflower plants had been killed by rust and drought so that the crop was in poor condition when it was ensiled. T. E. Woodward, in charge of the silage experiments at the experiment farm of the Dairy Division of the United States Department of Agriculture at Beltsville, Md., reports some difficulty in getting dairy cows to eat the sunflower silage, although its quality appeared to be good. Details are lacking regarding the condition of the sunflowers when they were put into the silo at the Michigan station. It is impossible, therefore, to explain its apparent lack of palatability. With the exception of the above-mentioned reports and that of the Pennsylvania experiment station (see p. 24) there has been little complaint about the palatability of sunflower silage.

At the Montana Agricultural Experiment Station cattle, sheep, and hogs ate sunflower silage readily and in sufficient quantities to prove its availability in the rationing of these animals. The West Virginia, Wyoming, and Idaho experiment stations, the University of Saskatchewan, and the Manitoba Agricultural College, in addition to numerous farmers, all report that sunflower silage is relished by dairy cows. It is safe to say, therefore, that silage made from sunflowers which are in good condition and at the right stage of development when cut will in most cases be consumed readily by dairy cows and most other kinds of live stock, with the possible exception of horses.

COLOR, TEXTURE, AND ODOR.

Good sunflower silage is usually a dark olive-brown color, much darker than corn or sorghum silage. In texture it compares favorably with corn silage when the sunflowers have been harvested at the right stage of maturity and stored properly. Most of the complaints regarding the texture of sunflower silage are the result of harvesting the crop too late. When the plants have been allowed to stand until the seeds are in the hard dough stage or even nearer ripe, the stems become woody and do not soften up in the silo.

Sunflower silage has a peculiar odor, which is rather strong, resinous, and somewhat sour, but not offensive. This odor may be one of the reasons why cattle sometimes hesitate to eat the silage when it is first offered to them.

ACIDITY OF THE SILAGE.

A determination of the acidity of sunflower silage was made by the chemical department of the Idaho Agricultural Experiment Station in 1919 (13). Three samples were used in the determinations. Samples 1 and 2 were taken from the silo at depths of 2 and 6 feet, respectively. Both of these samples were somewhat spoiled, as indicated by the dark color and disagreeable odor. Sample 3, on the other hand, seemed to have undergone a normal fermentation and had a good color and no disagreeable odor. The total acids, considering only sample 3, were found to be 1.37 per cent. The acidity of corn silage made from corn cut when the kernels were in the glazed stage, as determined by the senior author of the above-mentioned article, varied from 1.34 to 2.16 per cent in 1915 and was 1.81 in 1916. For oat-and-pea silage it was 1.66 and for wheat-and-pea silage 1.61 per cent. All these samples were taken from large silos, and the percentages are given on the basis of the composition of the silage as sampled (12).

As will be observed from these experiments good sunflower silage is less acid than corn silage or the silage made from a mixture of peas and small grains, and there can be no objection to it on account of its acidity.

RESULTS WITH DAIRY CATTLE.

The Montana, West Virginia, New Mexico, and Washington agricultural experiment stations, the Manitoba Agricultural College, and the University of Saskatchewan all report favorable results in feeding sunflower silage to dairy cows. At variance with their results are the rather unfavorable reports from the Pennsylvania and Michigan agricultural experiment stations and the United States Department of Agriculture field stations at Huntley, Mont., and Scottsbluff, Nebr.

The Montana Agricultural Experiment Station (4, p. 18-20) in a series of feeding experiments found that good sunflower silage can be substituted for a large part of the hay in a dairy cow's ration without diminishing the quantity of milk produced. The results indicated that $3\frac{3}{4}$ pounds of the silage equaled 1 pound of choice alsike-clover hay and 2.83 pounds 1 pound of good alfalfa hay.

Sunflower silage was compared with corn silage in feeding experiments with dairy cows at the West Virginia, Pennsylvania,

Michigan, and Washington agricultural experiment stations, at the United States Department of Agriculture field stations at Huntley, Mont., and Scottsbluff, Nebr., and at the Manitoba Agricultural College. The conclusions arrived at by the experimenters differ markedly. It is impossible to determine from available data just why the sunflower silage was palatable in one case and not in another. There are a sufficient number of failures, however, to indicate that more care and judgment are necessary to make good sunflower silage than to make good corn silage.

At the West Virginia (3) station the cows fed on a sunflower-silage ration produced per cow a daily average of 27.93 pounds of milk and 1.05 pounds of butter fat, while those fed corn silage produced an average per cow of 29.17 pounds of milk and 1.05 pounds of butter fat daily. In this test the milk produced by the cows fed sunflower silage averaged 3.74 per cent of butter fat and that produced from the corn-silage ration 3.60 per cent. At the Washington station (20) the cows ate more silage and less grain during the periods when given corn silage than while they were being fed sunflower silage. During the sunflower-silage periods the cows produced more milk but lost a few pounds in weight. While fed corn silage there was an appreciable gain in weight. The authors of the report conclude that sunflower silage in this test was approximately 92 per cent as valuable as corn silage. At the Manitoba Agricultural College (1) a feeding trial was carried on with seven cows from December 19, 1919, to April 1, 1920, the conclusion being that the cows maintained their milk flow and body weight fully as well on the sunflower silage as on the corn-silage ration.

The Pennsylvania station^s conducted a feeding test with sunflower silage in the winter of 1919-20 and with silage one-half sunflowers and one-half corn in the winter of 1920-21. In each case the standard of comparison was a good quality of corn silage. In the first test the cows while fed sunflower silage averaged 19.3 pounds of milk and 0.92 pound of butter fat per cow daily; while they were fed corn silage the average production per cow was 22.2 pounds of milk and 0.98 pound of butter fat daily. When the cows were changed from corn silage to sunflower silage there was a decrease of 23.5 per cent in the milk and 18.5 per cent in the butter fat produced. When the cows were changed from sunflower silage to corn silage there was an actual increase of 2.3 per cent in the milk produced, notwithstanding an advance of six weeks in the lactation

^s This preliminary statement of results obtained with sunflower silage by the Pennsylvania station in 1919 and 1920 was supplied by S. I. Bechdel, professor of dairy husbandry at the Pennsylvania State College. A complete report on the sunflower-silage feeding experiments will be published by the Pennsylvania Agricultural Experiment Station.

period. The sunflower silage, which was fed to the limit of the cows' appetites, proved unpalatable. Considerable trouble was experienced in getting the cows to eat enough of it. In this test the milk from the cows while fed sunflower silage averaged 4.75 per cent of butter fat and while on corn silage only 4.39 per cent. In the feeding test with the mixed corn and sunflower silage the cows produced an average of 20.2 pounds of milk and 0.88 pound of butter fat per cow daily, and 21.8 pounds of milk and 0.94 pound of butter fat daily on the corn silage. Again there was a decrease, in this case 14.5 per cent, in the milk produced when the cows were changed from corn silage to the mixed silage containing sunflowers. The corn silage used in the first test contained 30.6 per cent and the sunflower silage 26.6 per cent of air-dry matter. In the second test the corn silage contained 32.9 per cent and the mixed silage 25.8 per cent of air-dry matter.

Prof. Bechdel states his conclusions as follows: "From a study of the complete data of these experiments it is concluded that the use of sunflowers as a silage crop is not advisable on Pennsylvania farms except in a very few localities where corn is not always a sure crop. A mixture of sunflowers and corn, the crops being grown either alone or together, affords no advantage when the poorer quality of silage and the added difficulty of harvesting are taken into consideration."

The Michigan Agricultural College (11) reported that the milk production fell off 11.65 per cent when cows were changed from corn silage to sunflower silage. When the cows were taken from a sunflower-silage ration and fed both corn and sunflower silages in equal portions there was an increase of 7.06 per cent in the milk produced. When the change was made from this mixture of silages to pure corn silage there was again a decrease of 5.58 per cent in the milk produced. The results in Michigan seem to indicate that sunflower silage is less efficient than corn silage as a milk-producing feed, but that a combination of the two silages is preferable to either.

Holden (9, p. 27) in his report of the work at the Scottsbluff (Nebr.) Experiment Farm for 1918 and 1919 makes the following comment on the value of the different silage crops under test at that station: "From the data available at this experiment farm it is believed that the extra tonnage from silage corn over that from field corn will more than make up for the better quality of the field corn. It is further believed that the ensilage from silage corn is sufficiently higher in quality to offset the greater yield of sunflowers."

Sunflower silage was compared with sweet-sorghum silage as a feed for dairy cows at the New Mexico station (16) in the winter

of 1919-20. The author of the report states the results as follows: "The cows did not consume the sunflower silage as readily as the 'cane' silage, and they sometimes left a small quantity of it; but, notwithstanding this fact, the total amount of milk produced on sunflower silage was greater than that produced on 'cane' silage."

In a short feeding test at the University of Saskatchewan (5) sunflower silage was compared with oat silage as a roughage for dairy cows. The former produced slightly more milk, pound for pound, than oat silage.

The results at the University of Saskatchewan are supported by the report of the county agricultural agent of Wallowa County, Oreg., in the *Farm Journal* of January, 1921, p. 68. In response to a campaign for a wider use of sunflowers for silage, 14 silos were filled with sunflowers in 1919. Field peas and oats had previously been the chief silage crop of that county, and the sunflower silage proved more satisfactory than the pea-and-oat silage.

Another matter of considerable importance to the butter maker has developed in the feeding of sunflower silage at the field station of the United States Department of Agriculture at Ardmore, S. Dak. F. L. Kelso, farm superintendent, claims that considerable difficulty was experienced in manufacturing a satisfactory grade of butter while the sunflower silage was being fed. He says, in correspondence dated June 17, 1921: "It seemed almost impossible to get the butter to harden, although the flavor was fairly satisfactory. An ordinary churning required from an hour to an hour and a quarter while this silage was being fed. Under ordinary circumstances when corn or cane silage is fed it requires approximately 15 minutes to churn. The first churning that was done after discontinuing the feeding of sunflower silage required 22 minutes." This question of the effect on the butter is important and so far has been investigated very little.

Notwithstanding these adverse reports, the conclusion seems warranted that good sunflower silage is worthy of consideration as a constituent in the rations of dairy cows in localities where better silage crops are not available.

FEEDING TESTS WITH BEEF CATTLE.

The Montana Agricultural Experiment Station reports tests in feeding sunflower silage to beef cattle of practically all sizes and ages. Calves were fed, with good results, rations in which one-half or more of the roughage was sunflower silage. It was learned, however, that calves could not be put on a heavy feed of silage too rapidly; when this was done they went "off feed." This difficulty was not encountered with mature cattle. Two-year-old steers were

fed a limited ration of sunflower silage only for 30 days with good results, and mature beef cows thrived when fed sunflower silage in the morning and hay in the evening.

At the Wyoming station it was observed that cattle preferred the sunflower silage to good alfalfa hay or oat-and-pea silage. The silage was found especially valuable in Wyoming as a substitute for pasture during the winter, keeping both dairy cows and beef cattle in a thrifty growing condition.

The New Mexico station also fed sunflower silage to beef cows and young beef stock. It was compared with sweet-sorghum silage for this purpose and found to equal the latter in feeding value. What difference there was in the gains produced favored the sunflower silage (16).

At the University of Alberta (2) at Edmonton 54 steers were fed for 140 days in a comparison of three kinds of silage. Eighteen head were fed oat silage; 18 head, oat-and-pea silage, and 18 head, sunflower silage. The steers had all the silage and hay they desired in addition to a two-thirds grain and linseed-oil meal ration. The oat and oat-and-pea silages were both first-class. The sunflower silage was not so good, because the crop had to be harvested while it was immature. From 2 to 20 per cent of the plants were in bloom and one field was frosted before harvest. No difficulty was experienced in getting the steers to eat sunflower silage, and there was no trouble from scouring even while they were consuming 73 pounds of silage a day. In this experiment oat silage ranked first in rapidity and economy of gains, sunflower silage second, and oat-and-pea silage third.

There is little doubt from these experiments that sunflower silage can be used with good results in the rations of beef cattle.

USE OF SUNFLOWER SILAGE IN FEEDING SHEEP.

During the winter of 1917-18 the Montana Agricultural Experiment Station conducted an experiment in feeding sunflower silage to breeding ewes. This test was designed to indicate the value of sunflower silage in replacing a part of the alfalfa hay in the ration. The lot fed hay and oats was under test for 77 days, and the lot fed hay, silage, and oats for 74 days. The average gain per ewe during the test period was 13.2 pounds for the hay-fed lot and 12.4 pounds for those in which silage was included in the ration. This slight difference in gain was due for the most part, perhaps, to the slightly greater quantity of oats received by the first lot. The conclusion reached by the experimenters was that in feeding breeding ewes $2\frac{1}{2}$ pounds of sunflower silage is equal to 1 pound of alfalfa hay. No unfavorable results were noted in feeding the sunflower silage either before, during, or after lambing.

The Washington station (17, p. 17) found that "a lot of pure-bred lambs made an average daily gain of 0.225 pounds each when fed a daily ration of 1 pound barley, one-half pound cull beans, four-fifths pound of pea straw, and $2\frac{1}{2}$ pounds of sunflower silage." At the same station they were able to maintain breeding ewes in good condition on a daily ration consisting of 2 pounds of alfalfa hay and 3 pounds of sunflower silage.

At the Wyoming station sunflower silage was fed to growing ewe lambs in conjunction with native hay and three-fourths of a pound of a grain mixture daily. In a 42-day feeding period this group of lambs averaged 0.16 pound of gain daily. A similar group fed a like ration in which pea-and-oat silage was substituted for the sunflower silage averaged only 0.145 pound of gain daily.

The United States Sheep Experiment Station near Dubois, Idaho, completed about April 1, 1921, a 55-day feeding test on 1,700 ewes, with the following daily ration for each sheep:

Sunflower ensilage	2 pounds.
Alfalfa hay	$1\frac{3}{4}$ pounds.
No. 2 yellow corn	$\frac{1}{4}$ pound.

The silage was fed from racks 12 feet long, each of these racks accommodating 18 to 20 ewes. The first day half a pound of ensilage for each sheep was distributed. The quantity was gradually increased till the fifth day, when the full 2 pounds, with $1\frac{3}{4}$ pounds of hay and one-fourth pound of corn per head, were fed. This ration, divided into two feedings, was continued through the test.

In this band of sheep were 1,300 pregnant Rambouillet and cross-bred ewes from 2 to 7 years of age and 400 ewes coming yearlings the following spring, all in good condition at the beginning of winter. They were held on the range until a heavy snow on December 15; then taken to the feed lot and given 4 pounds of alfalfa hay per head daily until January 28. Because this hay was of poor quality the sheep lost condition during the period. From January 29 to March 24 the sheep received the ration mentioned above, containing sunflower ensilage, without hay the last five days, when open range was substituted. The test ended on March 24 when the sunflower ensilage was exhausted. At that time the entire band of sheep was stronger than at the conclusion of the alfalfa-hay feeding period on January 28, and was in good condition for lambing, with strong-stapled well-grown fleeces. Although the sheep had not tasted ensilage before this test, they ate it readily after the second day, preferring ensilage to hay. Only two died during the period, neither death being due to ensilage poisoning. Only three ewes were noticed that had lost their lambs.

Since no water was available at the feed yard the sheep ate snow. Although the sheep wintered well on the feed as described, it is be-

lieved that the ration could be improved by the addition of more sunflower ensilage.

FEEDING SUNFLOWER SILAGE TO HOGS.

The Montana Agricultural Experiment Station (4, p. 25-26) has done the principal work in comparing sunflower silage with alfalfa hay in a ration given brood sows. It was found that the sows would eat sunflower silage readily. During a part of the feeding period they consumed 4 pounds per head daily, in addition to a small quantity of skim milk and grain. The silage was fed for two months before farrowing began, throughout the farrowing period, and for a period of about four weeks thereafter, with no unfavorable results. It is acknowledged by the authors of the report on these experiments that but little of the grain in the ration can be replaced by sunflower silage. It did serve an excellent purpose, however, in keeping the sows in splendid condition, being as satisfactory in this respect as alfalfa hay.

SUNFLOWERS AS A SOILING CROP.

Sunflowers have been fed as a soiling crop to dairy cows by a number of experimenters, with good results. The chief disadvantage of this method of feeding is that the plants must be run through a cutter before they are used.

The Montana Agricultural Experiment Station (4, p. 22) compared sunflowers to corn as a supplement to pasture. Both crops were cut as needed and run through a silage cutter before being given to dairy cows during the latter part of their grazing season. "The cows ate the green sunflowers readily, kept up their milk flow, and apparently did well on the feed." The conclusion reached was that under the conditions of the experiment as described the sunflowers and corn were of equal feeding value.

A more extensive feeding test was later carried out at the same station, comparing sunflowers and corn as soiling crops. Six cows were fed all the chopped sunflowers they would eat and another six cows all the chopped corn they would eat. Both lots had access to a small pasture and in addition received the same grain ration. At the close of the test the corn was in the roasting-ear stage and the sunflowers were about 40 per cent in bloom. The cows fed sunflowers produced an average of 39.4 pounds of milk and 1.41 pounds of butter fat and those fed corn 38.1 pounds of milk and 1.38 pounds of butter fat per cow daily. During the feeding period of 28 days the cows fed sunflowers lost 7.8 pounds and those fed corn 20.4 pounds of live weight. The slight difference in results favoring sunflowers is no doubt due very largely to the fact that one cow in the corn-fed lot went "off feed" during the period. The results seem to confirm those of the first test and justify the conclusion that sunflowers can be used effectively as a soiling crop for dairy cows.

DISEASES OF SUNFLOWERS.

Rust⁹ is the most destructive disease of sunflowers. (Fig. 8.) It is common in southern Russia and has been reported at several points in the United States. Rust was prevalent on these plants at Hays, Kans., in 1920, and has done considerable injury to sunflowers in experiments at both the Michigan and Wisconsin stations. It decreases very decidedly the yield and also results in a poor quality of silage.

The best method of preventing rust injury appears to lie in the development of a rust-resistant variety. Frank Spragg and E. E. Down, in reporting on a variety test of sunflowers at the Michigan



FIG. 8.—Mammoth Russian sunflowers with the lower leaves killed by rust at the Hays Branch Station, Hays, Kans., 1920.

station in 1918 (see Mich. Agr. Quar. Bul., v. 2, no. 3, p. 128-129, 1920), claim for the South American variety Kaeurpher a certain measure of rust resistance. It may be, therefore, that a resistant variety will soon be found.

Some work in breeding a rust-resistant sunflower has been done in Russia. It was found by the investigator, F. A. Sazyperov, that the ornamental sunflower (*Helianthus agropyphyllus*) is resistant to the rust. None of the ordinary commercial varieties are known to be rust resistant. Hybrids were therefore made between one of the commercial varieties and the ornamental sunflower. In the second generation one-fourth of the hybrid plants were found resistant to the rust, although the season was exceptionally favorable to the spread of the disease. Among these resistant plants were

⁹ Rust (*Puccinia helianthi* Schw.), the damping-off fungus (*Pythium debaryanum* Hesse), downy mildew (*Plasmopara halstedii* Farl.), powdery mildew (*Erysiphe cichoracearum*), and wilt (*Sclerotinia* sp.), in addition to the parasitic plants *Orobancha cumana* Wall. and *Homeosonia nebulella* Hb. are all said to attack sunflower plants.

individuals which appeared interesting from an agricultural standpoint. Sazyperov concludes, therefore, that it is possible to obtain an agricultural variety resistant to the rust.

INSECTS ATTACKING SUNFLOWERS.

In the warmer and drier parts of the United States insects do considerable damage to sunflowers. At both Amarillo and Chillicothe, Tex., the stalks of the sunflowers were girdled by a larva or white grub which resembled very closely the larva of the June bug. This larva worked at or just below the surface of the soil and usually killed the plant completely or injured it so badly that all growth ceased. Another insect, also at Chillicothe, girdled the stalk just beneath the head, causing the head to drop over.

Besides the above insects several forms of beetles and grasshoppers infest the heads of sunflowers at blooming time and do considerable damage to the seed crop. In 1918 and 1919 grasshoppers very much reduced the yield of sunflowers at Scottsbluff, Nebr., by eating out the terminal bud before the plants headed. Thrips are often abundant on the heads, and aphides, or plant lice, occur in quantity on the leaves. Sunflowers are, however, less injured by chinch bugs than corn, and in some localities where these insects are troublesome sunflowers may prove valuable in replacing corn as a silage crop.

Strangely enough, these insects are all less abundant on sunflowers in the regions of low summer temperature where the plant promises to be most important. Cockerell (6) presents a partial list of the insects which are known to visit sunflowers in Colorado, but in most cases he does not indicate the damage caused.

LITERATURE CITED.

ANONYMOUS.

- (1) 1920. Manitoba:—Sunflower ensilage for milk production. *In Agr. Gaz. Canada*, v. 7, no. 10, p. 818-819.
- (2) 1921. Silage for fattening steers. (Summary of report by A. A. Dowell and G. L. Flack, University of Alberta, Edmonton, Canada). *In Nor'-West Farmer*, v. 40, no. 11, p. 627.
- (3) ANTHONY, ERNEST L., and HENDERSON, H. O.
1920. Sunflowers vs. corn for silage. *West Va. Agr. Exp. Sta. Circ.* 32, 8 p., 1 fig.
- (4) ATKINSON, ALFRED, NELSON, J. B., ARNETT, C. N., JOSEPH, W. E., and TRETSEVEN, OSCAR.
1919. Growing and feeding sunflowers in Montana. *Mont. Agr. Exp. Sta. Bul.* 131, 29 p., 4 fig.
- (5) BRACKEN, JOHN.
1919. Saskatchewan:—Sunflower silage. *In Agr. Gaz. Canada*, v. 6, no. 6, p. 542-543.

- (6) COCKERELL, T. D. A.
1914. The entomology of *Helianthus*. *In* *Entomologist*, v. 47, no. 614, p. 191-196.
- (7) HANSEN, DAN.
1920. The work of the Huntley Reclamation Project experiment farm in 1918. U. S. Dept. Agr. Dept. Circ. 86, 32 p., 5 fig.
- HOLDEN, JAMES A.
(8) 1918. The work of the Scottsbluff Reclamation Project experiment farm in 1917. U. S. Dept. Agr., Bur. Plant Indus., West. Irrig. Agr. (W. I. A.) Circ. 27, 28 p., 1 fig.
- (9) 1921. The work of the Scottsbluff Reclamation Project experiment farm in 1918 and 1919. U. S. Dept. Agr. Dept. Circ. 173, 36 p., 2 fig.
- (10) JOSEPH, W. E., and BLISH, M. J.
1920. Studies on the digestibility of sunflower silage. *Mont. Agr. Exp. Sta. Bul.* 134, 8 p.
- (11) MICHIGAN AGRICULTURAL EXPERIMENT STATION.
1920. Sunflower silage. *In* *Mich. Agr. Exp. Sta. Quart. Bul.*, v. 2, no. 4, p. 163-164.
- (12) NEIDIG, RAY E.
1918. Acidity of silage made from various crops. *In* *Jour. Agr. Research*, v. 14, no. 10, p. 395-409. Literature cited, p. 408-409.
- (13) ——— and VANCE, LULU E.
1919. Sunflower silage. *In* *Jour. Agr. Research*, v. 18, no. 6, p. 325-327.
- (14) PALMER, EDWARD.
1871. Food products of the North American Indians. *In* U. S. Dept. Agr. Rpt., 1870, p. 404-428, pl. 19-28.
- (15) PUTNAM, G. W.
1920. Sunflower experiments. *In* *Mich. Agr. Exp. Sta. Quart. Bul.*, v. 3, no. 2, p. 49-52, 2 fig.
- (16) QUESENBERRY, GEORGE R.
1920. Crops that may be used for silage. *In* *N. Mex. Farm Courier*, v. 8, no. 4, p. 4-6.
- (17) SCHAFER, E. G., and WESTLEY, R. O.
1921. Sunflower production for silage. *Wash. Agr. Exp. Sta. Bul.* 162, 20 p., 4 fig. References, p. 19.
- (18) SHAW, R. H., and WRIGHT, P. A.
1921. A comparative study of the composition of the sunflower and corn plants at different stages of growth. *In* *Jour. Agr. Research*, v. 20, no. 10, p. 787-793. Literature cited, p. 792-793.
- (19) WILEY, HARVEY W.
1901. The sunflower plant: Its cultivation, composition, and uses. U. S. Dept. Agr. Div. Chem. Bul. 60, 31 p., 2 fig., 1 pl.
- (20) WOODWARD, E. G.
1920. Sunflower silage vs. corn silage. *In* *Wash. Agr. Exp. Sta., 30th Ann. Rpt., 1919/20 (Bul. 158)*, p. 18-20.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1046

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief, in cooperation with the
Kansas Agricultural Experiment Station



Washington, D. C.

May, 1922

RUST RESISTANCE IN WINTER-WHEAT VARIETIES.¹

By LEO E. MELCHERS, *Plant Pathologist*, and JOHN H. PARKER, *in Charge of Crop Improvement, Kansas Agricultural Experiment Station; Agents, Office of Cereal Investigations.*

CONTENTS.

	Page.		Page.
Scope of the investigation.....	1	Evidence of specific rust resistance.....	24
Review of the literature.....	2	Agronomic value of Kanred wheat.....	26
Nursery experiments.....	4	Summary.....	27
Greenhouse experiments.....	14	Literature cited.....	30
Comparison of nursery and greenhouse results	23		

SCOPE OF THE INVESTIGATION.

A project to determine the rust resistance of existing varieties of winter wheats and to breed new varieties for rust resistance was begun in 1911 at the Kansas Agricultural Experiment Station, in cooperation with the Office of Cereal Investigations of the United States Department of Agriculture. The first two years were devoted to preparatory work, when no infection of stem rust was produced. The writers² took charge of the work in 1913, and the data given herein are those obtained since that time.

The investigation outlined in 1913 had two major purposes: (1) To study the rust resistance of about 130 varieties and strains of winter and spring wheats, particularly to the stem rust, *Puccinia graminis tritici* Erikss. and Henn.,³ in the field and in the greenhouse; and (2) to study the inheritance of rust resistance in wheat and to produce hybrids adapted to commercial use.

¹ Paper No. 183 of the Department of Botany and Plant Pathology and No. 136 of the Department of Agronomy, Kansas Agricultural Experiment Station.

² The writers wish to acknowledge their indebtedness to Mr. Victor H. Florell and Mr. M. N. Levine, of the Office of Cereal Investigations, who assisted in the greenhouse studies and in other phases of the investigation.

³ *Puccinia graminis tritici*, as used in this bulletin, has reference to those strains of stem rust used in the experiments in 1915, 1916, and 1917. In 1915 a strain was used to which Kanred, P1066, and P1068 were only partially resistant, while in 1916 and 1917 strains were used to which these varieties were very resistant. The strains used in 1916 and 1917 may have been one or more of the several strains which at present are known not to cause normal infection of these varieties.

Climatic conditions at Manhattan, Kans., are generally unfavorable for the development and spread of the stem rust of wheat; the development of a suitable technique for the production of severe epidemics in the rust nursery was therefore an essential part of these investigations.

Special attention was given to those varieties which are most promising agronomically.

If a variety of hard red winter wheat could be found which was resistant to stem rust and suitable for Kansas conditions, breeding for rust resistance would be much simpler than if it becomes necessary to cross with varieties of the durum or emmer groups.

Hayes, Parker, and Kurtzweil (13)⁴ recently have found that "there is an indication of linkage of durum or emmer characters and rust resistance, since the production of rust-resistant durums or emmers in the F_2 and F_3 generations is comparatively easy and the production of resistant common wheats much more difficult." Moreover, the only known rust-resistant varieties of the emmer or durum groups are spring forms, a fact which complicates the task of obtaining a rust-resistant winter wheat from such a cross. Winter hardiness, high yield, and good milling quality also are essential for the success of any variety of wheat in Kansas, which increased the complexity and difficulty of the problem. To obtain accurate information as to the resistance of existing varieties of winter wheat was, therefore, the first important step.

REVIEW OF THE LITERATURE.

Differences in the resistance of wheat varieties to rust were known to exist as early as 1841, when Henslow (15) observed that some wheats were injured less by rust than others. La Cour (23) and Little (26) made similar observations. Bolley (3) noted that hardy and stiff-stemmed varieties with smooth, fibrous leaves seem to resist rust for a longer time. Anderson (1) observed that hard, flinty wheats are more resistant than others, believing that this might be due to a larger proportion of silica in the plant. Cobb and Farrer (35) and Farrer (35) found that wheat varieties resist leaf rusts and stem rusts in different degrees. Hitchcock and Carleton (16) state that hard varieties of wheat suffer least from rust in Kansas and early varieties are likely to mature before being seriously injured. Henning (14) and Eriksson and Henning (11) found that certain wheat varieties resisted different kinds of cereal rusts.

It has long been known that some of the emmers (*Triticum dicoccum*) and certain varieties of durum wheat (*Triticum durum*) show marked resistance to stem rust. Carleton and Chamberlain (9) and Carleton (8) called attention to this in connection with the com-

⁴The serial numbers (italic) in parentheses refer to "Literature cited" at the end of this bulletin.

mercial value of the durums. Carleton (8), in discussing the stem-rust epidemic on wheat in 1904, observed that no wheat varieties, with the exception of einkorn and some of the durums, spelts, and emmers, showed marked resistance under all conditions. He stated further, that during ordinary seasons when stem rust may be quite prevalent the hard-kerneled Russian winter wheats are considerably more resistant to rust than other varieties ordinarily grown.

Bolley (4, 5), Biffen (2), and Nilsson-Ehle (33) were among the first to conduct wheat-breeding experiments with the definite object of obtaining rust-resistant varieties. No definite plan or method of study, however, was described until Johnson (20) explained the methods used for producing an artificial rust epidemic in Minnesota and furnished a working basis for the studies which have been made since in this country in breeding cereals for rust resistance. These methods are further described by Freeman and Johnson (12). They state that certain varieties, such as Extra Squarehead in Sweden, American Club in England, and Rerrarf and Ward's Prolific in Australia, have been shown to be resistant to rust. They add, however, that some of these varieties can not be said to be universally rust resistant, as their behavior in different countries to different biologic forms of rust is variable.

Field experiments have verified early observations that some of the durums and emmers are much more resistant than the common spring-wheat varieties. Stakman (37) found this to be true in both field and greenhouse experiments. Melchers and Parker (29, 31) recently have called attention to the resistance of three winter-wheat varieties to stem rust and leaf rust. Waldron and Clark (42) have described a variety of common wheat named Kota and stated that it was resistant to the strain or strains of stem rust prevalent at Fargo, N. Dak., Brookings, S. Dak., and St. Paul, Minn., in 1918. These authors state that "this resistance is decidedly greater than that possessed by the common spring wheats and second only to the more resistant durum wheats." Clark, Martin, and Smith (10) speak of the rust behavior of varieties of durum and common wheat grown during the seasons of 1914 to 1919 at several field stations in the northern Great Plains. They state that none of the varieties of common wheat grown is really rust resistant, but early-maturing varieties have ripened before the rust has developed extensively and are sometimes rust escaping. Most varieties of durum wheats are more or less rust resistant, as compared with common wheats. Acme, Monad, and D-5 are known to be especially rust resistant. In years of heavy rust infection these varieties have produced the highest yields. When grown under comparable conditions in these and other experiments, the D-5 variety shows the greatest resistance of all varieties to stem rust.

NURSERY EXPERIMENTS.

METHODS AND MATERIALS.

Because of the infrequent occurrence of natural epidemics of stem rust under Kansas conditions,⁵ it was necessary to study varietal resistance in a rust nursery (Pl. I, figures 1 and 2), following the general plan suggested by Johnson (20). This rust nursery was located near Manhattan, Kans., on land which is low and slopes slightly toward the south and west. Along the south side of the nursery is a hedge of common barberry bushes (Pl. I, fig. 2). A large drainage ditch on the south side carried off the surplus water. Because of the likelihood of frequent heavy rains during the crop season, the rust nursery was sown in slightly elevated plats, separated by depressed alleys, which received the surplus water and carried it into the main ditch. The rust nursery has been sown in various ways. At first a plat 1 rod square was used for each variety, but it was found impossible to produce severe epidemics of stem rust on large areas under Kansas conditions. The plats, therefore, were reduced to a single rod row and in 1915 to 5-foot nursery rows spaced 10 inches apart. The seeds are sown 3 inches apart in the row. A small hand plow was used for opening a furrow and a seeding board with notches at regular intervals served to obtain uniformity in spacing the seed.

The spring varieties generally were sown during the last week in March or the first week in April in rows close to the winter-wheat rust nursery.

The rust used in these experiments up to and including 1917 was obtained from the Minnesota Agricultural Experiment Station. In 1914, 1915, and 1916 the urediniospores came from greenhouse cultures of *Puccinia graminis tritici*, but in the fall of 1917 cultures were used from rusted wheat plants obtained in the field. These were found later to be a new strain of stem rust (30). The stock cultures of rust which were used in these field experiments were cultured on Improved Turkey (Kansas No. 2382), a variety which has been found in these experiments to be very susceptible to stem rust. When the leaves produced uredinia which were sporulating abundantly they were used in one of two ways: (1) The leaves were clipped from the plants, placed in a few quarts of water, the urediniospores removed, and the liquid used as a spray on the wheat plants in the rust nursery, or (2) the potted wheat plants bearing uredinia were used as centers of infection in the nursery.

⁵ The only natural epidemic known to the writers occurred in 1904. In 1915 and 1916 stem rust was very prevalent in many fields in Kansas and in some instances there was an appreciable loss. In 1919 stem rust was uniformly present in eastern and central Kansas, and although it was difficult to estimate the actual injury caused by stem rust it was one of several factors which reduced the yield and quality of wheat.



FIG. 1.—GENERAL VIEW OF THE WHEAT-RUST NURSERY.

The investigation of the comparative rust resistance of varieties of wheat at the Kansas Agricultural Experiment Station was conducted here. The arrows indicate the location of rotary sprayers.



FIG. 2.—ROW OF BARBERRY BUSHES ADJACENT TO THE WHEAT-RUST NURSERY.

Each arrow indicates the location of a rotary sprayer.

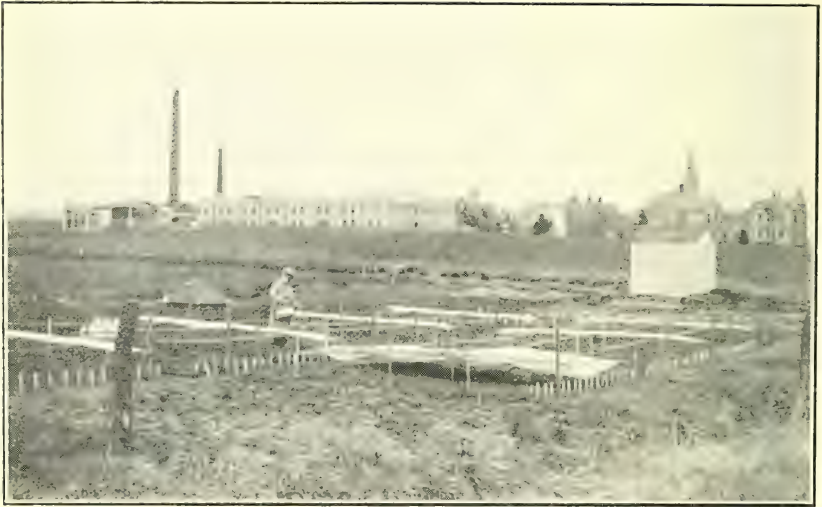


FIG. 1.—REMOVABLE CANVAS COVERS USED IN THE WHEAT-RUST NURSERY TO RETAIN MOISTURE.

A urediniospore sprayer is shown in operation.



FIG. 2.—POT CONTAINING RUSTED SEEDLINGS FROM THE GREENHOUSE.

Used in establishing infection centers in the wheat-rust nursery.

When sprays of urediniospore decoction were used in the study at Manhattan, Kas., a small knapsack pressure sprayer was employed. All sprays were applied in the evening; if possible during periods of moist, cloudy weather. The plants were first sprayed with water and then with the urediniospore spray. Sprays of urediniospores were found to be unreliable, however, because of the hot dry winds which frequently occur in Kansas during the late spring and early summer. In order partially to overcome this difficulty, removable canvas covers were placed over a wooden framework which was built over the plats. These covers were used the day following the urediniospore sprays and aided materially in retaining moisture. They were easily handled by one man, being unrolled from a long strip of wood and drawn over the nursery plats, to be fastened at the corners as shown in Plate II, figure 1.

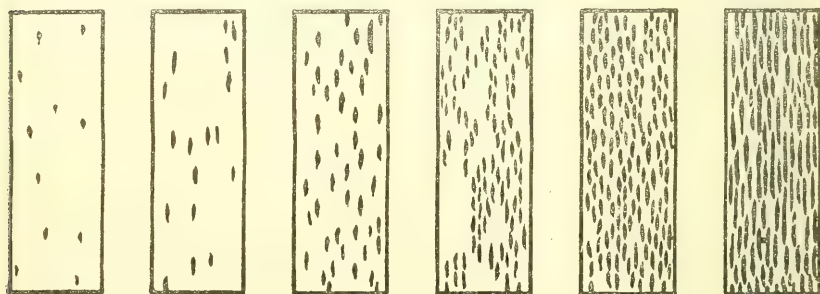
Several attempts have been made to inoculate plants in the rust nursery in the fall. Not only was it difficult to obtain satisfactory infection, but it was of doubtful value in view of the fact that it is questionable whether stem rust lives over winter in Kansas to any great extent (17).

On account of the unsatisfactory results obtained with the urediniospore sprays, the infection-center method of obtaining an epidemic was tried. This method is somewhat similar to inoculating plants in the field, but it is much simpler and more certain to give satisfactory results. The inoculated seedlings are carried from the greenhouse to the plats, where they spread the infection. Numerous infection centers were located in each plat, so as to provide ample spore material (Pl. II, fig. 2).

Most of the rust cultures for these experiments were grown on seedlings in 2½-inch flowerpots, two seedlings in each pot. Frequently 4-inch pots were used, as they held more seedlings and did not dry out so rapidly. It was found that if small galvanized-iron pans were placed between the rows of wheat in the rust nursery early in the spring and filled with pots of inoculated seedlings, a most successful center of infection could be established. (Pl. II, fig. 2). The pans were kept filled with water at all times.

As soon as the seedlings died or the rusted leaves no longer produced urediniospores, the pots were replaced with a new set. In this manner the wheat plats were continually exposed to rust infection. It recently has been found that if plants in the heading stage are inoculated in the greenhouse and used in place of seedlings for the centers of infection, their usefulness in the field continues longer than that of seedling plants; hence, they are much more satisfactory. It was found also that wherever the centers of infection were located the rust obtained a start and spread rapidly from the centers to all adjacent plants.

In 1914 only two urediniospore sprays were applied, one on April 19 and the other on May 23. Neither of these sprays was followed by any noticeable rust infection. Canvas covers were not used. In 1915 urediniospore sprays were given on April 20, 21, 27, and 29, and on May 7, 10, 20, 22, and 31. Inoculated seedlings were transplanted into the soil in vacant rows, which were left for that purpose, this being the first attempt to use the infection-center method. Canvas covers were used and a severe epidemic was caused, as shown by the data on rust infection. In 1916 urediniospore sprays were given on April 6, 13, 14, 20, 25, 26, and 29, and on May 1, 4, 16, 19, and 27. Canvas covers were used. In addition to these sprays the infection-center method was employed. A severe epidemic resulted. In 1917 sprays of urediniospores were given on May 23 and 29, and on June 6. A few hand inoculations in the field were made in the spring, but the efforts were mostly directed toward establishing in-



A, 5 per cent. B, 10 per cent. C, 25 per cent. D, 40 per cent. E, 65 per cent. F, 100 per cent.

FIG. 1.—Scale for estimating rust, illustrating six degrees of rustiness used in estimating the percentage of stem-rust infection. The shaded spots represent rust, and the figures represent approximately the rust percentages computed on the basis of the maximum of surfaces covered by rust as shown in the 100 per cent figure (F). Figure F in the diagram represents 37 per cent of actual rust-covered surface and is arbitrarily selected as 100 per cent. The other percentages are in terms of figure F.

fection centers. It was evident from the results obtained that the latter method was sufficiently dependable to warrant the discontinuance of urediniospore sprays.

The common barberry (*Berberis vulgaris* L.; see Pl. I, fig. 2), planted south of the rust nursery plats, furnished some æcial infection in 1915, 1916, and 1917. Straw, bearing telia of stem rust, was placed around each shrub in the fall, so as to provide the necessary teliospore material to infect the barberry leaves in the spring.

The final field notes were taken during the latter part of June or early in July, at the time the nursery was harvested. These included the percentage of stem rust, estimated in accordance with the scale shown in figure 1 and used by the Office of Cereal Investigations of the Bureau of Plant Industry, United States Department of Agriculture. Notes on the type of head, plumpness of grain, and other characters also were recorded.

Erratum.

The fourth line of the last paragraph of text on page 7 should read as follows:
stains of stem rust (29, 30) , and Marquis, Haynes Blue-

The varieties grown in the rust nursery included the commonly grown hard red winter wheats of the Crimean group, such as Turkey and Kharkof, and the varieties of soft red winter wheat grown in eastern Kansas and other soft red winter-wheat districts: Some of the varieties were obtained from the Office of Cereal Investigations of the Bureau of Plant Industry and others from the agricultural experiment stations of other States. The strains grown under a pedigree number, and so designated in Table 1, represent pure-line selections made by Prof. H. F. Roberts, formerly of the department of botany, Kansas Agricultural Experiment Station. These strains were turned over to the department of agronomy in 1910, and seed was obtained from that department when the study of wheat varieties for rust resistance was begun. Not all the varieties have been grown throughout the period of experiment, because some of them were found to be of little or no agronomic value. Some were shown to be extremely susceptible to stem rust, and others were eliminated because of complete winter killing. A small number of spring-wheat varieties were grown, to obtain comparative data on rust infection.

BREEDING PLAT.

Certain varieties of spring and winter wheats were grown in a breeding plat each year to serve as material for crossing. The winter-wheat varieties were sown in the fall at the time the varieties were sown in the rust nursery. Considerable space was left between the rows of winter wheat, to allow for seeding spring wheats for crossing. Occasionally a few of the spring varieties bloomed at the same time as the winter wheats, thereby simplifying the work of making the crosses. Generally, however, it was necessary to sow such spring varieties in the greenhouse about the first of February. These were transplanted to the breeding nursery in April and May, thus providing some of the spring-wheat plants, which were in flower at the same time as the winter varieties.

Crosses have been made between Kanred (Kansas No. 2401), Kansas No. 2414, and Kansas No. 2415,⁶ three closely related winter-wheat varieties which are resistant to leaf rust (31) and to certain strains of stem rust (29, 30); also between Marquis, Haynes Blue-stem, and Preston, varieties of spring wheat which are susceptible to stem rust. The F_1 , F_2 , and F_3 generations have been grown to maturity, and data on the inheritance of resistance to stem rust (*Puccinia graminins tritici*) have been obtained. These results, however, are not presented in this bulletin.

⁶These varieties have been known as P762, P1068, and P1066, respectively. They have recently been given Cereal Investigations numbers as follows: C. I. 5146, C. I. 5879, and C. I. 5880, respectively.

RESULTS OF THE NURSERY EXPERIMENTS.

The percentage of stem rust found on the varieties grown in 1915, 1916, and 1917 and the 3-year average for all varieties grown in all three seasons are shown in Table 1. Notes on the quality of grain also are given for the years 1916 and 1917.

The varieties are arranged according to type and are grouped as to the characters, winter or spring, awned or awnless, glabrous or pubescent glumes, and soft or semihard to hard kernel. All of the winter-wheat varieties with the exception of Binkel Club are common wheats (*Triticum vulgare*). The spring grains include varieties of common wheat, as well as durum wheat (*T. durum*), emmer (*T. dicoccum*), and einkorn (*T. monococcum*).

The "Identification numbers" include the "Pedigree number," as used by Prof. H. F. Roberts; the "Kansas number," which is an accession number assigned by the department of agronomy; and the C. I. number, used by the Office of Cereal Investigations of the Bureau of Plant Industry.

TABLE 1.—Stem-rust infection of wheat varieties after artificial inoculation in the nursery at Manhattan, Kans., in the years 1915, 1916, and 1917, together with data on kernel quality in 1916 and 1917.

[KEY TO SYMBOLS.—Identification numbers (columns 1 and 3): C. I.=Cereal Investigations, H=hybrid, K=Kansas, P=pedigree. Rust infection (columns 5 to 7): T=trace, Wk=winterkilled. Quality of kernels (columns 9 and 10): E=excellent, F=fair, F-=poor to fair, F+=a grade better than fair, F±=variable quality (some poor to fair, some fair to good), G=good, G-=a grade poorer than good, G+=a grade better than good, G±=variable quality (some fair to good, some good to excellent), P=poor, Vp=very poor.]

Group 1.—AWNED, GLUMES GLABROUS, KERNEL SEMIHARD TO HARD.

Season, class, and identification number.	Kansas No.	C. I. No.	Varietal name.	Stem-rust infection (per cent).				Quality of kernels.	
				1915	1916	1917	3-year average.	1916	1917
1	2	3	4	5	6	7	8	9	10
WINTER VARIETIES.									
Common wheats:				Per cent.	Per cent.	Per cent.	Per cent.		
P647.....	2356		Japan.....	40	55	Wk		F+	-----
P651.....	2357		Russian.....	25	68	Wk		F+	-----
P675.....	2368		Red Winter Java.....	25	70	Wk		F±	-----
P678.....	2370		do.....	50	75-	Wk		F	-----
P693.....	2376	1665		50	60	88	66	F+	F-
P706.....	2382	5592	Improved Turkey.....	50	57+	58	55	P	P
P707.....	2383		Red Winter Java.....	45	47	Wk		G±	-----
P711.....	2385			25	52	95	57.3	G±	F-
P712.....	2386			40	32	80	50.6	G	F-
P717.....	2388	1437	Crimean.....	25	45	95-	55	F+	G
P721.....	2390			40	30	T to 40	35	G	G
P722.....	2391			35+	42	95	57.3	G-	F-
P732.....	2398			40+	65	98	67.6	F	F
P733.....	2399			45	60	Wk		F-	-----
P736.....				65	48	90+	67.6	G	P
P737.....				65	54	65	61.3	F-	F-
P742.....	2434	1538	Uta.....	65+	42	78	61.6	F-	P
P744.....				40	38	95	57.6	P	F
P745.....	2433	1539	Torgova.....	35	45+	90	56.6	F-	F
P746.....				25	55	97	52.6	F	P
P750.....	2411	1543	Beloghina.....	25+	47	85	52	F-	P

TABLE 1.—*Stem-rust infection of wheat varieties after artificial inoculation in the nursery at Manhattan, Kans., in the years 1915, 1916, and 1917, together with data on kernel quality in 1916 and 1917—Continued.*

Group 1.—AWNED, GLUMES GLABROUS, KERNEL SEMIHARD TO HARD—Continued.

Season, class, and identification number.	Kansas No.	C. I. No.	Varietal name.	Stem-rust infection (per cent).				Quality of kernels.	
				1915	1916	1917	3-year average.	1916	1917
1	2	3	4	5	6	7	8	9	10
WINTER VARIETIES—continued.									
Common wheats—Con.				Per cent.	Per cent.	Per cent.	Per cent.		
P751.....	2427	1543	Beloglina.....	25	35	60	40	F	F
P752.....				40	40	Wk		F—	
P753.....				50	60	88	60	F—	G—
P754.....				35+	40+	95	56.6	F—	P
P755.....				30+	65+	68	54.3	F—	P
P757.....				30+	67	50	49	F—	P
P758.....	2419	1544	Beloglina.....	35	65+	95	65	P	F
P759.....				20—	40	70	43.3	P	P
P762.....	2401	5146	Kanred.....	40 to 70	10	10	25.0	G	E
P771.....	2436		Power Fife × Jonathan.	40	45	85	56.6	F+	F
P772.....				45	50+	95	63.3	F	G
P773.....				55—	55—	97	69	F—	G—
P774.....	2418		Power Fife × Jonathan.		60+	80+		G—	G+
P877.....				60	65	70	65	F—	
P882.....				60	48	90	66.0	P	G
P889.....	2409	6217	Turkey.....	20+	40	50	36.6	P	G
P935.....	2404		Bucanera.....		42	70+		G	F+
P951.....	2417		Scottish Rank	40	45+	88	57.6	F	P
P967.....				60+	62	90	70.6	P	G
P973.....				45+	65—	90	66.6	F—	F
P1000.....	2435		Hickling.....	55+	85—	75	71.6	F+	P
P1003.....				35	82	Wk		G	
P1008.....	2428		Victoria.....	60+	82+	78	73.3	G	F
P1013.....				30	75	50	51.6	F—	F—
P1036.....	2412	2479	Romanella.....	35—	77	Wk			
P1038.....	2422	2478	Fern or April....	25	85+	85	65	F—	F—
P1066.....	2415	5879		45	5+	15	18.3	G+	G
P1068.....	2414	5880		40+	5+	5 to 25	20	G+	G
P1078.....	2416	1543	Beloglina.....	25—	50+	85	53.3	F—	F—
P1080.....				60—	60+	78	66	F—	F
P1111.....				30	78	Wk		G—	
P1119.....				45	45	Wk		G—	
P1128.....				40	65+	85	63.3	F—	F
P1131.....				40+	70+	97	69	F—	F
P1134.....	2420	1436	Crimean.....	30	85+	85	66.6	F—	P
P1161.....	2410	1787		65	40	Wk		G+	
K34.....		5147	Nebraska No. 28.		60	Wk		F—	
K570.....		1558	Turkey.....		45	95		F+	P
K2048.....		5797	Alberta Red.....			88			F
K2101.....		6213	Red Winter.....			70+			F
K2123.....		6214	Defiance Hard Winter.			Wk			
P2141.....	2413	6474		30—	60—	95+	61.6	G—	F—
K35.....		1442	Kharkof.....		60+	88		F—	F

Group 2.—AWNED, GLUMES GLABROUS, KERNEL SOFT.

WINTER VARIETIES.									
Common wheats:									
P638.....	2358		Binkel Club.....		68	Wk		F	
P668.....	2365		Michigan Bronze		90+	70		G	P
K51.....		1981	Dietz Longberry		90—	Wk		P	
C. I. 1945.....			Lancaster.....		88	Wk		F—	
K36.....		2008	Mammoth Red.....		95	Wk		F—	
C. I. 1973.....			New Amber Longberry.		85	Wk		P	
K47.....		2980	Stoner.....		90—	Wk		F	

TABLE 1.—*Stem-rust infection of wheat varieties after artificial inoculation in the nursery at Manhattan, Kans., in the years 1915, 1916, and 1917, together with data on kernel quality in 1916 and 1917—Continued.*

Group 3.—AWNED, GLUMES PUBESCENT, KERNEL SOFT.

Season, class, and identification number.	Kansas No.	C. I. No.	Varietal name.	Stem-rust infection (per cent).				Quality of kernels.	
				1915	1916	1917	3-year average.	1916	1917
1	2	3	4	5	6	7	8	9	10
WINTER VARIETIES.									
Common wheats:				<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>		
P724.....	2392	.....	.....	40+	50	68	52.6	F+	F
P1071.....				20+	45	Wk	.....	F+	.....
P1082.....		1571	Turkey.....	25	50	65	46.6	F+	P
K49.....		3277	Virginia.....	.....	85+	95+	.....	P	P
(?).....			Velvet Chaff.....	.....	65	Wk	.....	G-	.....

Group 4.—AWNLESS, GLUMES GLABROUS, KERNEL SOFT.

WINTER VARIETIES.									
Common wheats:									
P718.....	2389	.....	.....	30	40	95+	55	G	G-
P739.....	.....	.....	.....	80+	40-	60	60	F	F
P740.....	2441	1535	Berdiansk.....	.....	65	70	.....	F-	P
P741.....	.....	.....	.....	85	40-	95	73.3	P	P
P748.....	.....	.....	.....	40-	65+	85+	63.3	F+	G-
P765.....	2402	.....	.....	.....	65+	90+	.....	F-	F+
P871.....	.....	.....	.....	40-	60+	80	60	F-	F+
P970.....	2403	.....	.....	.....	65	90	.....	F-	F
P980.....	2405	.....	North Allerton.....	40+	68	75	61	P	F-
P1064.....	2440	6218	Zimmerman.....	30+	60+	70	53.3	F	F
P1092.....	2406	6216	Currell.....	25+	75	90	63.3	G-	P
K39.....	.....	1733	Dawson Golden Chaff.....	.....	75+	Wk	.....	F	.....
K38.....	.....	1744	Early Genesee Giant.....	.....	77	Wk	.....	Vp	.....
K42.....	.....	1915	Purple straw.....	.....	60	Wk	.....	F-	.....
K40.....	.....	1923	Fultz.....	.....	67	Wk	.....	F+	.....
K52.....	.....	1969	Michigan Amber.....	.....	80	Wk	.....	P	.....
C. I. 1979.....	.....	.....	Poole.....	.....	85	Wk	.....	F-	.....
K48.....	.....	1980	Fultz-Mediterranean.....	.....	90+	Wk	.....	P	.....
K46.....	.....	2997	Kofod.....	.....	65	Wk	.....	F	.....
C. I. 3326.....	.....	.....	Currell.....	.....	95-	Wk	.....	P	.....

Group 5.—AWNLESS, GLUMES PUBESCENT.

WINTER VARIETIES.									
Common wheats:									
P1073.....	2408	.....	Jones × Red Fife.....	.....	95	Wk	.....	P-	.....
K44.....	.....	1933	Jones Winter Fife.....	.....	90	Wk	.....	P	.....
K50.....	.....	.....	Mealy.....	.....	85	Wk	.....	P	.....

Group 6.—AWNED, GLUMES GLABROUS (TRITICUM VULGARE, T. DURUM, AND HYBRIDS).

SPRING VARIETIES.									
Common wheats:									
C. I. 2958.....	.....	.....	Preston (Minn. No. 188).....	35	40	85	53	.....	P
H. 3×111.....	.....	4783	Iumillo × Preston.....	25	40	80	48	.....	P
H. 4×942.10.....	.....	4788	Kubanka × Preston.....	.....	.....	68	.....	G-	F-
H. 6×2223.....	.....	4789	Kubanka × Blue-stem.....	.....	.....	60	.....	G	F-

TABLE 1.—*Stem-rust infection of wheat varieties after artificial inoculation in the nursery at Manhattan, Kans., in the years 1915, 1916, and 1917, together with data on kernel quality in 1916 and 1917—Continued.*

Group 7.—AWNED, GLUMES PUBESCENT.

Season, class, and identification number.	Kansas No.	C. I. No.	Varietal name.	Stem-rust infection (per cent).				Quality of kernels.	
				1915	1916	1917	3-year average.	1916	1917
1	2	3	4	5	6	7	8	9	10
SPRING VARIETIES.									
Common wheats:				<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>		
C. I. 2442.....				5—	10	10 to 40	13	.....	G

Group 8.—AWNLESS, GLUMES GLABROUS.

SPRING VARIETIES.									
Common wheats:									
C. I. 1517.....				35+	50	98	61	.....	F—
C. I. 3641.....				25	65	95	61	.....	G—
C. I. 2873.....				25	45	85	51	.....	P
				Ghirka Spring.. Marquis..... Glyndon Fife (Minn. No. 163).					

Group 9.—AWNLESS, GLUMES PUBESCENT.

SPRING VARIETIES.									
Common wheats:									
C. I. 2874.....				35+	40	90	55	.....	P
				Haynes Blue-stem (Minn. No. 169).					

Group 10.—AWNED, GLUMES GLABROUS.

Durum wheats:									
H. 3×122A12.....				Iumillo × Pres-ton.		5—			G—
C. I. 1493.....				Arnautka.....	55	75			F
C. I. 1494.....				do.....	(a)				
C. I. 1443.....				Gharinovka.....		40			G—
C. I. 1513.....				Beloturka.....					G
C. I. 1736.....				Iumillo.....	25	60	5—	30	G
C. I. 2094.....				Kubanka.....	5—	b 25	10	13	G
C. I. 3320.....				Monad.....		5—			G—
C. I. 3320.....				Monad Selection.....		5—			G—
C. I. 3322.....				Pentad (D-5).....		T			G
C. I. 5284.....				Acme.....		30			G

Group 11.—AWNED, GLUMES GLABROUS, WHITE.

Emmer and Einkorn:									
C. I. 1522.....				White Spring Emmer.					
C. I. 1524.....				do.....	(c)	5	T		
C. I. 4781.....				do.....		T	5		
C. I. 1526.....				Yaroslav emmer.....	T				
C. I. 4013.....				Khapli emmer.....	(d)	T	T		
C. I. 2433.....				Common einkorn.....	T	8	T to 35		

a Heavy on base; on upper culms, trace.

b On necks.

c Fairly heavy at base; on culms, trace.

d Heavy on necks; on culms, trace.

The names are those which appear in the records of the Kansas Agricultural Experiment Station. Most of the varieties in the bearded, glabrous-glumed, hard red-kerneled group are very similar to the well-known Turkey and Kharkof varieties.

Nearly all the winter-wheat varieties proved to be very susceptible to stem rust (Pl. III). Three of the pedigreed strains, however, were found to be remarkably resistant. These were Kanred and two unnamed varieties, P1066 and P1068. These three pure-line selections differ morphologically from Turkey and Kharkof in the greater length of the short awn or beak found at the tip of the outer or empty glume. The average length of the beak in these three varieties is considerably greater than in the case of Turkey, Crimean, and Kharkof.⁷ The variety P762 (Kansas No. 2401) was named Kanred (from Kansas Red) and distributed to farmers in 1914. The other two resistant strains, P1066 and P1068, are very similar to Kanred; in fact, the three strains seem to be morphologically identical. They appear to differ slightly in certain agronomic characters, such as yield, winter hardiness, and grain quality. The experimental data which are available indicate that each of these other two selections is equal to Kanred in yield and other agronomic qualities, although they have not been grown as long in plats at the agronomy farm and have not been compared at the branch experiment stations or in cooperative experiments with farmers.

These three strains did not attract any particular attention in 1915, as they seemed as heavily rusted (40 to 70 per cent) as many of the other varieties, but in 1916 and 1917 very different results were obtained.⁸ They were almost free from stem rust (Pl. IV). The estimated infections of rust on these three varieties in 1916 were 10, 5, and 5 per cent respectively, and in 1917 they were 10, 15, and 5 to 25 per cent, respectively, compared to the maximum figures of 95 to 98 per cent on other varieties in the same seasons.

The only other variety of winter wheat which gave any evidence of resistance was Kansas No. 2390. The infection of stem rust on plants of this variety was estimated at 40 per cent in 1915, at 30 per cent in 1916, and as "Trace to 40 per cent" in 1917. This variety was much less heavily rusted than many other varieties in 1916 and 1917, but it does not appear to be nearly as resistant as Kanred, P1066, and P1068.

⁷ This distinguishing character was first called to the attention of the writers by Carleton R. Ball and J. Allen Clark, of the Office of Cereal Investigations.

⁸ In the light of present knowledge of the existence of several biologic strains of stem rust, with different infection capabilities, the results in 1915 are easily explained as being due to the presence in the rust nursery of one or more strains of stem rust which were able to attack these varieties.



A. HOEN & CO. LITH.

TYPICAL INFECTION OF STEM RUST OF TURKEY WHEAT.

This represents the susceptible strain of this variety used as a check in the wheat-rust nursery in 1916.



A. HOCH & CO. LITH.

A TYPICAL PLANT OF KANRED WHEAT FROM THE RUST NURSERY IN 1916.
Note the very slight rust infection. The other pure lines (P 1066 and P 1068) presented a similar appearance.



TYPICAL RUST INFECTION OF TWO VARIETIES OF WHEAT IN 1916.

A, Mealy, a susceptible variety of soft red winter wheat; B, Ghirka Spring wheat, also very susceptible.

A. HOEN & CO. LITH.

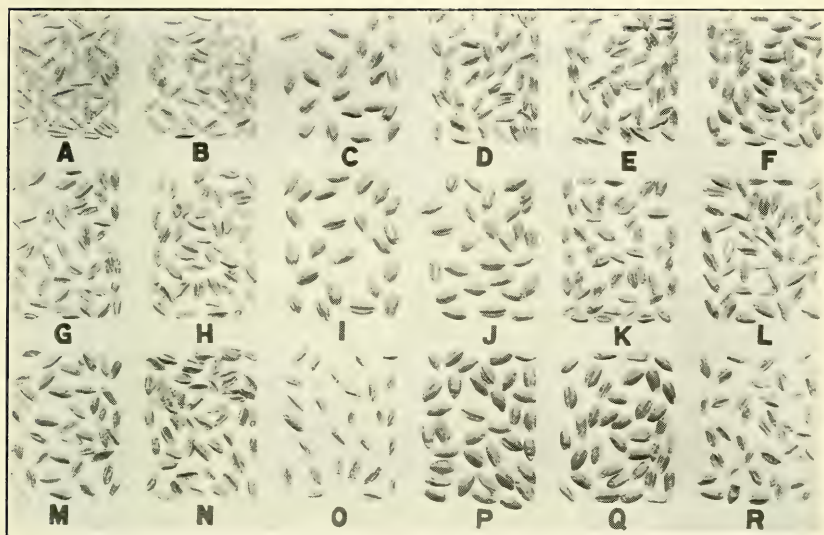


FIG. 1.—KERNELS OF SUSCEPTIBLE AND RESISTANT WHEAT VARIETIES IN 1916.

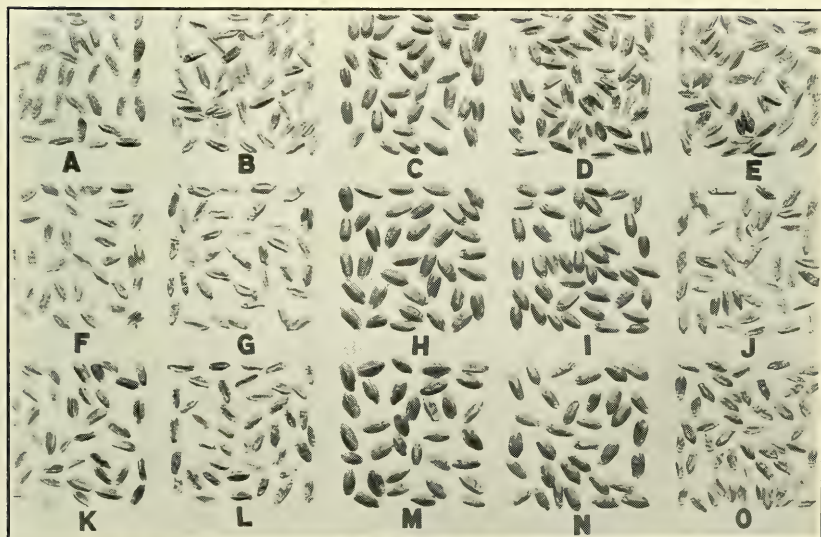


FIG. 2.—KERNELS OF SUSCEPTIBLE AND RESISTANT WHEAT VARIETIES IN 1917.



MOIST CHAMBER USED FOR INOCULATED SEEDLINGS IN THE GREENHOUSE.

A fine spray of water at *A* is used to lower the temperature.

All varieties of soft red winter wheat were found to be susceptible to stem rust. Plate V, A shows a typical plant of Mealy, a very susceptible variety.

Several of the varieties of spring wheat showed evidence of being resistant. Other varieties, such as Ghirka Spring (Pl. V, B), were found to be very susceptible. Black Persian was the only variety of common spring wheat which showed marked signs of resistance.

Among the durum wheats, Beloturka (C. I. No. 1513), Iumillo (C. I. No. 1736), Kubanka (C. I. No. 2094), Monad (C. I. No. 3320), and D-5 (C. I. No. 3322) all proved rather resistant to stem rust. A hybrid between Iumillo and Preston (No. 3 $\times$ 122A12) also was very resistant. This hybrid resembles the durum parent in type of head.

All of the strains of emmer gave some evidence of being resistant, as did the one strain of einkorn. Khapli emmer (C. I. No. 4013), although slightly rusted, never showed the large linear uredinia which develop on susceptible varieties.

Usually a rather close relationship is shown between the extent of stem rust recorded and the quality of grain produced by a given variety. The grain of certain varieties, however, sometimes is severely injured by a medium quantity of rust, while other varieties with a higher percentage of rust infection will produce heavier grain.

Kanred, P1066, and P1068 were all low in quantity of rust in 1916 and 1917, and all produced good heavy plump kernels. Factors other than rust infection, of course, influence grain quality, but it was very evident in 1916 and 1917 that the three rust-resistant varieties produced better grain than the similar but more severely rusted varieties grown in near-by rows.

Typical kernels of resistant and susceptible varieties produced in the wheat-rust nursery in 1916 and 1917 are shown in Plate VI. Table 2 presents data showing the percentage of rust infection on the varieties of which kernels are shown in Plate VI. The letters in the first column of the table correspond with those of figures 1 and 2 of the plate.

TABLE 2.—*Stem-rust infection on susceptible and resistant varieties of wheat grown in the rust nursery at Manhattan, Kans., in 1916 and 1917.*

1916.

Identification.		Name.	Class.	Rust infection.
Pl. VI, fig. 1.	Pedigree or other number.			
A.....	P758.....		Hard red winter.....	<i>Per cent.</i> 65
B.....	P759.....		do.....	40
C.....	P762.....	Kanred.....	do.....	10
D.....	P771.....		do.....	45
E.....	P772.....		do.....	50
F.....	P773.....		do.....	55
G.....	P1038.....		do.....	85
H.....	P1064.....		do.....	60
I.....	P1066.....		do.....	5
J.....	P1068.....		do.....	5
K.....	P1071.....		do.....	45
L.....	P1078.....		do.....	50
M.....	P1036.....		do.....	77
N.....	Check.....	Turkey.....	do.....	45
O.....	C. I. 1517..	Ghirka.....	Hard red spring.....	50
P.....	C. I. 3322..	D-5.....	Red durum.....	
Q.....	P721.....		Hard red winter.....	30
R.....		Mealy.....	Soft red winter.....	85

1917.

A.....	P758.....		Hard red winter.....	95
B.....	P759.....		do.....	70
C.....	P762.....	Kanred.....	do.....	Trace.
D.....	P765.....		do.....	90
E.....	P877.....		do.....	70
F.....	P1038.....		do.....	85
G.....	P1064.....		do.....	70
H.....	P1066.....		do.....	5
I.....	P1068.....		do.....	5
J.....	P1078.....		do.....	85
K.....	Kans. 2048..	Alberta Red.....	do.....	88
L.....	Minn. 169..	Haynes Bluestem.....	Hard red spring.....	85
M.....	C. I. 2094..	Kubanka.....	Durum.....	10
N.....	P721.....		Hard red winter.....	40
O.....	C. I. 3277..		Soft red winter.....	95

GREENHOUSE EXPERIMENTS.

To check the nursery results similar experiments under controlled conditions were conducted in the greenhouse.

INOCULATION METHODS.

Nearly all the varieties, both winter and spring, which were used in the field were inoculated in the seedling and heading stages in the greenhouse. Careful records of the inoculated plants of each variety have been kept and their behavior compared with the behavior of the same variety in the field. The number of plants which can be grown under greenhouse conditions is more or less limited, and for this reason conclusions from such experiments should always be drawn with caution.

INOCULATION OF SEEDLINGS.

In inoculating seedlings the first leaf was inoculated and all others were trimmed off. The uredinial material came from stock cultures grown on Improved Turkey (Kansas No. 2382), or some other sus-

sceptible variety. The inoculation method used was described by Melchers (28) and was a modification of the method proposed and used by Kellerman (22) and Carleton (7) in their studies of cereal and other rusts. This is a satisfactory method where the supply of rust is limited, as there is little chance for loss of spores. The spore supply was collected in a Petri dish and applied to the seedlings by means of a flattened or a rounded needle. The leaves to be inoculated were first thoroughly dampened by stroking them several times between the fingers previously moistened in water. Tap water was used with satisfactory results, although Melhus and Durrell (32) have shown that tap water may have a toxic effect on the germination of certain kinds of rust spores.

In the studies in the greenhouse the seedlings were grown in 2½-inch pots, illustrated in figure 2. Fifteen pots, each containing 2 seedlings, or 30 seedlings in all, constituted one series of each variety.



FIG. 2.—Seedlings grown to determine rust resistance of wheat varieties under greenhouse conditions. Pots 1 and 2 contain seedlings of a susceptible variety used as a check; Nos. 3 to 6 contain seedlings of P1068. Each of the two seedlings in each pot is trimmed to a single leaf blade which is inoculated.

In most cases it was not necessary to inoculate more than one series of plants, but if the results were at all doubtful a second series was inoculated. Hundreds of inoculations were made on seedlings of Kanred, P1066, and P1068. Two to four seedlings of Improved Turkey (Kansas No. 2382) were used as checks for each series.

After inoculation, the seedlings were kept in damp chambers for 48 hours, after which they were removed and placed on the greenhouse bench. Bell jars were first used, but these proved impracticable. An inexpensive and effective damp chamber, shown in Plate VII, was devised. It consisted of a galvanized-iron washtub with a pane of glass for a cover.⁹

About one-quarter of an inch of water was placed in the bottom of each chamber, to keep the air saturated. The chambers were kept in the shade, so as to maintain a temperature of 50° to 70° F. In warm weather, a spray of water was directed upon the damp chambers to reduce the temperatures. Difficulty was experienced during

⁹ Cylinders made of galvanized iron (without permanent top or bottom), with a diameter of 15 inches and a height of 12 inches, have been used more recently. A removable piece of glass is used for a top. If these cylinders stand on damp sand, sufficient moisture is supplied to keep the chamber saturated, and the potted seedlings do not stand in water. Damp chambers of this type have proved very satisfactory.

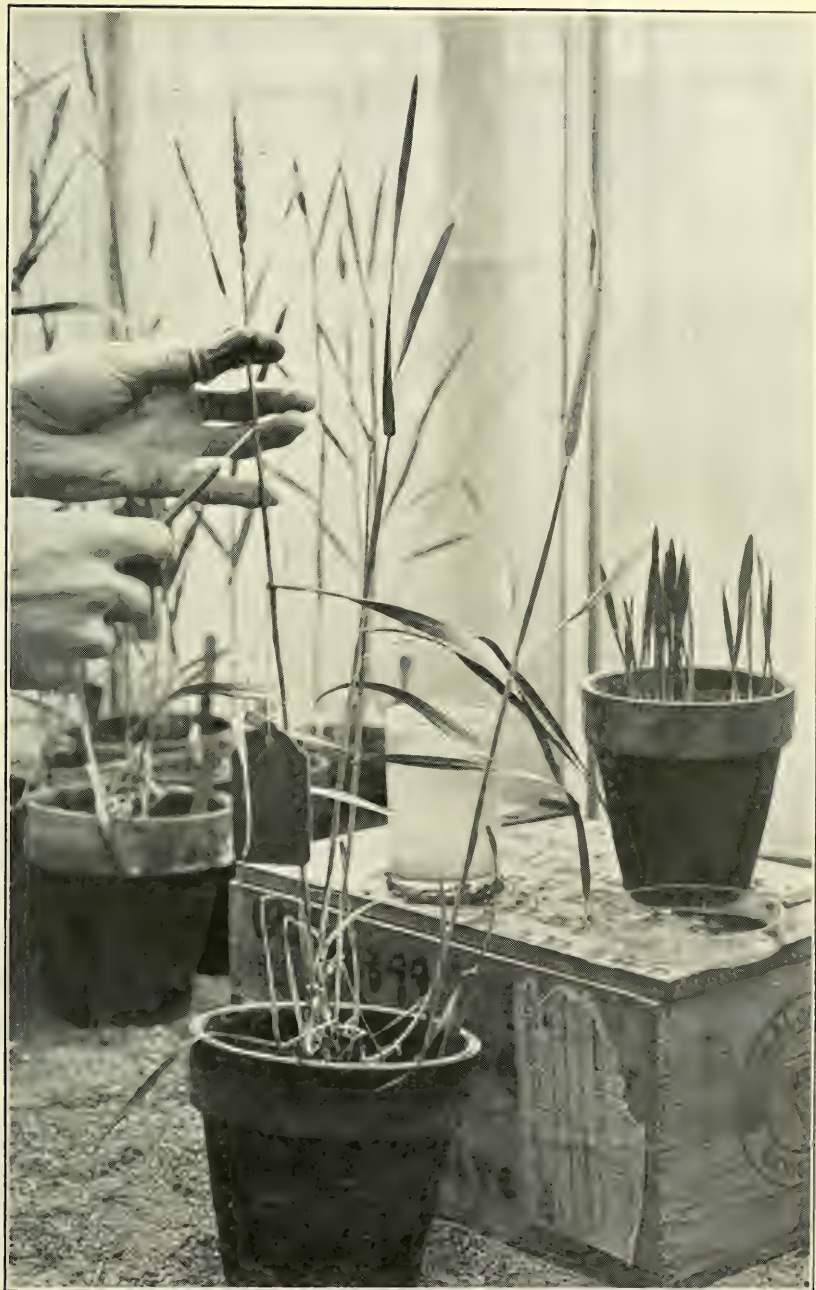
the first year in carrying the cultures through the summer, on account of the prolonged periods of temperatures ranging from 100° to 110° F. It was found that sprays of water directed upon the chamber not only cooled the air in the greenhouse but in addition kept the temperature in the damp chambers within a few degrees of that of the water itself. By such means a difference of 11° C. between the temperature inside and that outside the chambers was obtained, as shown by some of the readings at different dates during July and August.

Johnson (21) found that the maximum temperature at which urediniospores of *Puccinia graminis* would germinate in a normal manner was about 88° F., though the experiments of the writers have shown that temperatures of 80° to 95° F. do not prevent normal infection. However, temperatures of 65° to 70° F. are believed to be the most favorable for inoculations with stem rust. These methods have been satisfactory in every respect; 100 per cent of infection always was obtained on plants of susceptible varieties, including checks, and it is believed the notes on resistance or susceptibility are as dependable as can be obtained under greenhouse conditions. The methods described, however, might not give as satisfactory results with other cereal rusts.

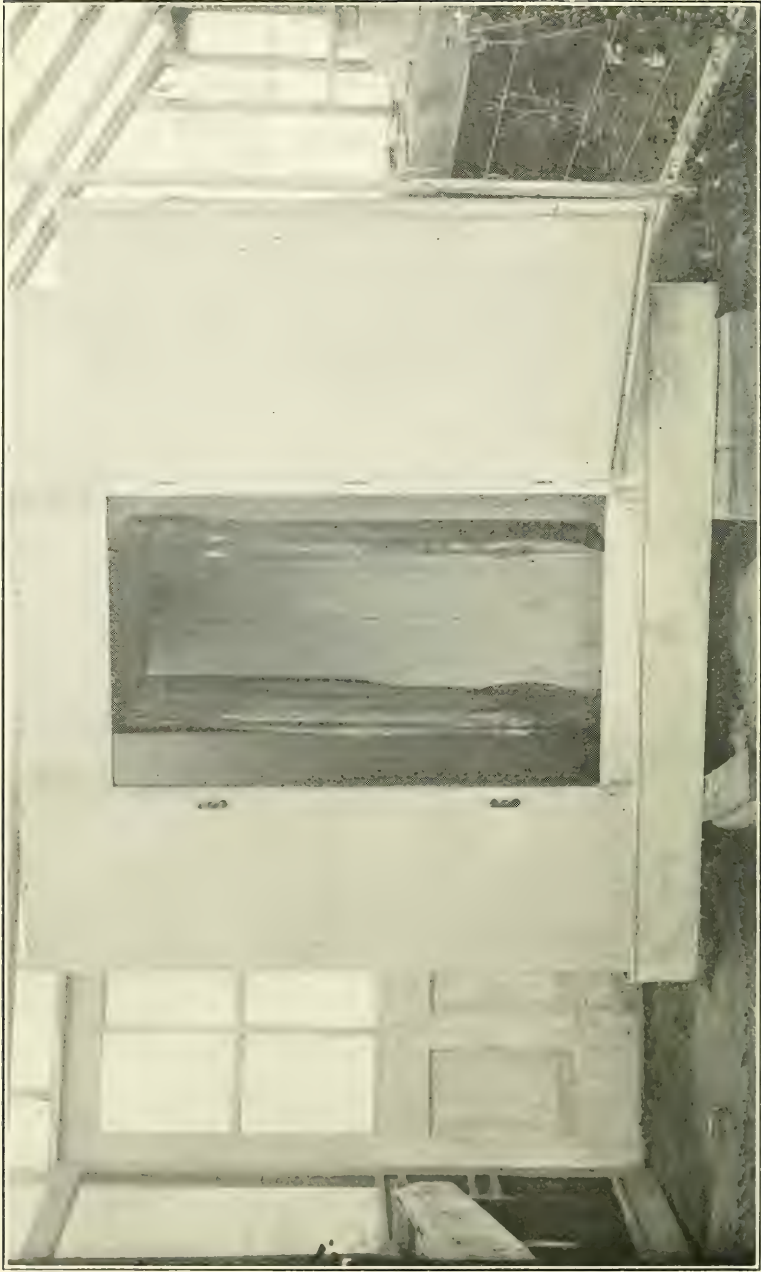
INOCULATION IN THE HEADING STAGE.

One plant of each variety which was grown in the rust nursery was allowed to develop to the heading stage in the greenhouse. One seed was sown in each pot in October. It has been found that by maintaining the proper temperature, either spring or winter wheat can be matured and normal seed developed in the greenhouse. Hutcheson and Quantz (18) have shown that temperatures from 55° to 70° F. are best suited to this purpose. In the experiments of the writers, where plants were grown to the heading stage, a night temperature of about 50° F. was maintained, but not infrequently the night temperature during the early stages of growth fell as low as 35° or 40° F. The temperature was kept below 75° F. during the daytime whenever possible.

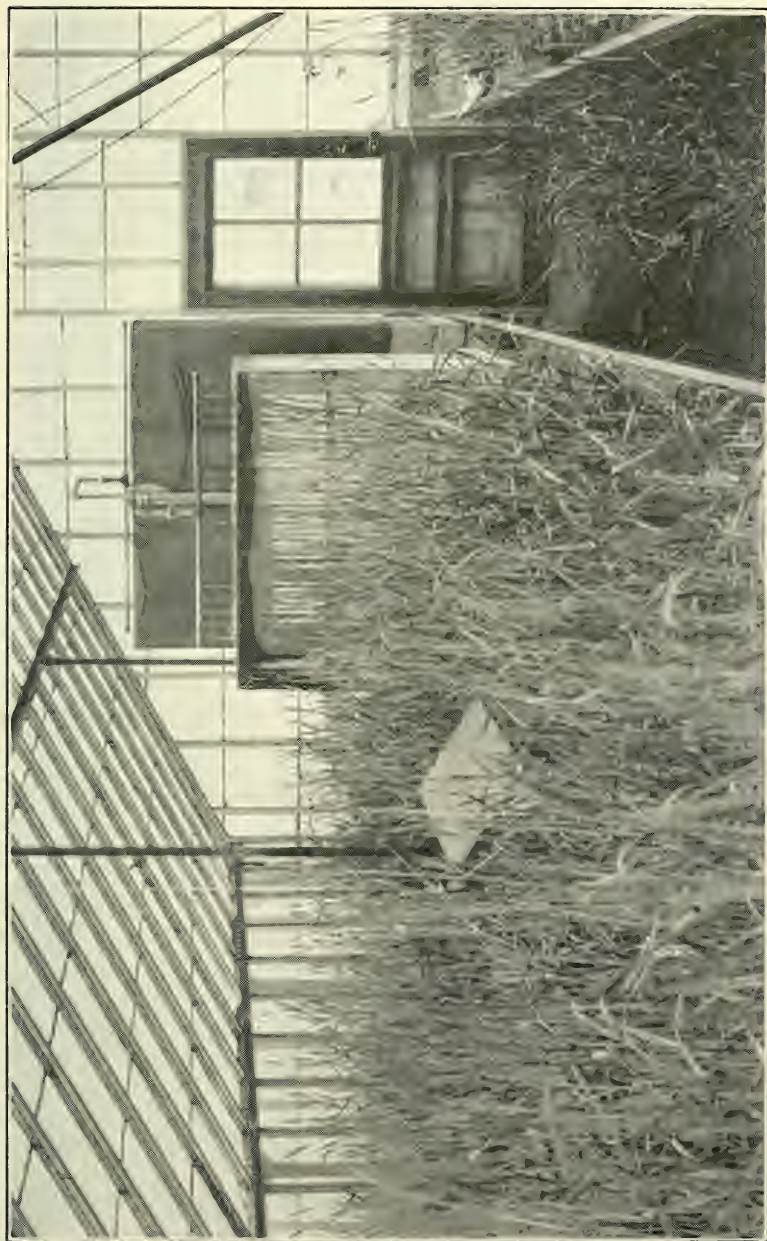
The plants were inoculated as soon as the heads were well out of the boot and the neck or peduncle exposed, as illustrated in Plate VIII. Two to six culms of each variety were inoculated with stem rust. In the case of Kanred, P1066, and P1068 the inoculations included a much larger number of plants. In some cases the culms of these three varieties were reinoculated a number of times, so as to expose them to infection as often as possible and at different periods of development. The uppermost leaf blade and the sheath of each culm of all varieties grown were thoroughly inoculated, as were the necks, glumes, and awns. These plants were then placed for a period of 48 to 72 hours in a specially constructed galvanized-iron damp chamber, similar to the one described by Parker (34). This damp chamber is of sufficient



METHOD OF INOCULATING WHEAT PLANTS AT THE TIME OF HEADING AND SEEDLINGS AT THE INOCULATING STAGE.



LARGE SHEET-METAL MOIST CHAMBER USED FOR WHEAT PLANTS INOCULATED AT HEADING TIME.
The pan of water and wick maintain a high degree of humidity.



LARGE WATER-COOLED MOIST CHAMBERS USED FOR PLANTS INOCULATED AT HEADING TIME.

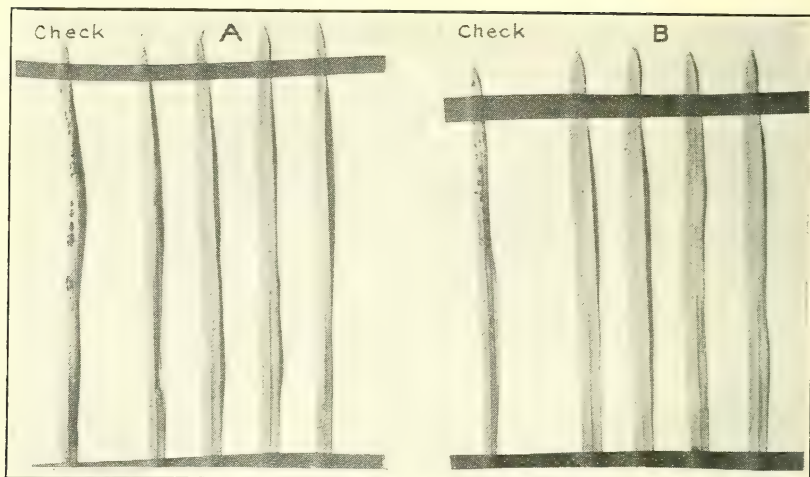


FIG. 1.—RUST RESISTANCE OF TWO VARIETIES OF WINTER WHEAT IN 1918.

Seedling leaves of P1066 (*A*) and Kanred (*B*), both inoculated on April 22 and photographed on May 11. Compared with the rusted leaves of the susceptible check (shown at the left of each group) these leaves are seen to be entirely free from flecks and uredinia.

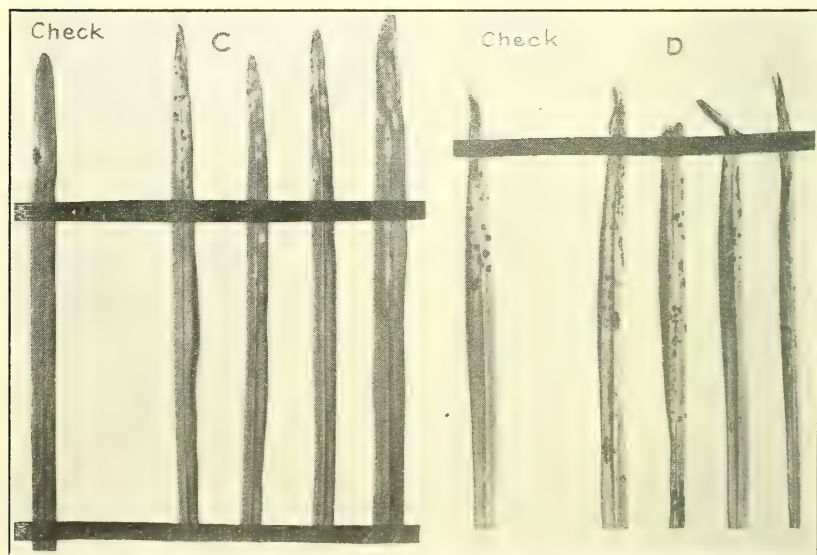


FIG. 2.—RUST SUSCEPTIBILITY OF TWO VARIETIES OF SPRING WHEAT IN 1917.

Seedling leaves: *C*, Arnautka (C. I. 1493), inoculated on March 29 and photographed on April 19; *D*, hybrid 3 x 122A12, showing normal uredinia in this stage, inoculated on April 4 and photographed on April 27. Although known to be resistant to some strains of stem rust in the field, these two varieties show visible signs of infection when inoculated with the same strain of rust used with *A* and *B* (fig. 1, above).

COMPARATIVE RUST RESISTANCE OF SOME WINTER AND SPRING VARIETIES OF WHEAT.

size to accommodate about 72 plants. About half an inch of water was kept in the bottom of the chamber and a pan of water was suspended from the top. A cloth wick was placed over this pan and was allowed to hang down on two sides, as shown in Plate IX. This helped to keep the air saturated. A glass top allowed sufficient light to enter the moist chamber, so that the plants did not become etiolated during the incubation period. On warm days a stream of water was allowed to flow over the top, as illustrated in Plate X. This helped to maintain a cool temperature within the chamber. Cloths were hung over the outside walls to help distribute the water evenly. An overflow pipe in the pan at the bottom of the chamber carried away the surplus water. The inoculated plants were placed on inverted empty flowerpots, to avoid setting them in water.

RESULTS OF THE GREENHOUSE EXPERIMENTS.

The results obtained from greenhouse inoculations are shown in Table 3. Very heavy infection always was obtained on the checks and the susceptible varieties, but in the case of Kanred, P1066, and P1068 no uredinia appeared. Some of the spring-wheat varieties also showed only slight to moderate infection. The peduncles, glumes, and awns of all susceptible varieties were just as readily infected at heading time as were the seedlings. In the case of the three resistant varieties, if any portion of the head becomes infected it is the awn. No signs of infection, however, could be noticed on plants of the three resistant varieties with the exception of a few indefinite flecks on the culms. A plant of Improved Turkey was included with each set of varieties and on being inoculated was placed in the damp chamber and maintained under the same conditions. These checks always became heavily infected. It is evident that favorable conditions for infection were present, as uredinia were produced on plants of Khapli emmer (C. I. No. 4013), Kubanka durum (C. I. No. 2094), and other varieties of emmer and durum wheat which are known to be resistant to stem rust.

The "type of infection," is shown in the table by symbols (explained below) indicating the relative resistance or susceptibility. The results of inoculations in the seedling and heading stages should be regarded as a corollary to the field results, however. It is hardly safe to draw final conclusions on the comparative resistance of varieties from experiments in the seedling stage alone, as the conditions under which the inoculations must be made are certain to vary and frequently may cause a different interpretation of the results. This is especially true where only a few seedlings are inoculated. A variety inoculated with a given strain of stem rust may show a somewhat different type of infection when inoculated at another time, even though the check which is run with every series may show a normal infection.

TABLE 3.—Results of inoculating wheat varieties with stem rust in the greenhouse at the Kansas Agricultural Experiment Station at Manhattan, Kans., in the winter of 1916-17.

[Key to identification numbers (columns 1 and 3): C. I.=Cereal Investigations, H=hybrid, K=Kan³³³ P=pedigree.]

Group 1.—AWNED, GLUMES GLABROUS, KERNEL SEMIHARD TO HARD.

Season, class, and identification number.	Kansas No.	C. I. No.	Varietal name.	Stem-rust infection.		Type of infection. ^a		Remarks.
				Seedlings.	Headed plants.			
				Number inoculated.	Number infected.	Number inoculated.	Number infected.	
				Seedlings.	Headed plants.	Seedlings.	Headed plants.	
WINTER VARIETIES.								
Common wheats:—								
Continued.								
P373.....				30	30	3	3	
P647.....	2356		Japan.....	30	13	6	6	Purple color. ^b
P651.....	2357		Russian.....	30	29			
P675.....	2368		Red Winter Java	30	28			Do.
P678.....	2370		do.....	30	28	3	3	
P693.....	2376	1665		30	22	3	3	
P706.....	2382	5592	Improved Turkey.	30	23	3	3	
P707.....	2383		Red Winter Java	30	30	9	9	
P711.....	2385			30	30			Plant died.
P712.....	2386			30	29	6	6	
P717.....	2388	1437	Crimean.....	30	30	3	3	
P721.....	2390			30	27	3	3	
P722.....	2391			30	29	6	6	
P732.....	2398			30	28	3	3	
P733.....	2399			30	30	3	3	Purple color.
P736.....				30	30	3	3	
P742.....	2434	1538	Ulta.....	30	30	4	4	
P744.....				30	26	5	5	
P745.....	2433	1539	Torgova.....	30	30	3	3	
P746.....				30	30	3	3	
P750.....	2411	1543	Beloglina.....	30	30	6	6	
P751.....	2427	1543	do.....	30	30	3	3	
P752.....				8	8			
P753.....				30	30	3	3	
P754.....				30	16	3	3	
P755.....				30	30			
P757.....				30	30	3	3	Do.
P758.....	2419	1544	Beloglina.....	30	24	6	6	
P759.....				30	28	6	6	
P762.....	2401	5146	Kanred.....	6	6	3	3	
P771.....	2436		(Power Fife × Jonathan.	28	21			
P772.....				30	30	3	3	
P773.....				30	30	3	3	
P774.....	2413		Power Fife × Jonathan.	30	30	6	6	
P877.....				30	27	3	3	Purple color.
P882.....				30	30	3	3	
P889.....	2409	6217	Turkey.....	28	22	3	3	
P935.....	2404		Bucanera.....	8	8			
P951.....	2417		Scottish Rank..	30	30	3	3	
P967.....				30	7	3	3	
P973.....				30	30			
				30	30	6	6	
				30	28	3	3	
				30	30			

^a The symbols indicate the type of infection, as explained on page 22.^b Under certain conditions some varieties produced a purple color surrounding the uredinia; where this was pronounced it is indicated in the table.^c Since the completion of this work about 200 additional seedlings have been inoculated, with the same results.^d Since these inoculations were made, many additional culms have been inoculated, with the same results.

TABLE 3.—Results of inoculating wheat varieties with stem rust in the greenhouse at the Kansas Agricultural Experiment Station at Manhattan, Kans., in the winter of 1916-17—Continued.

Group 1.—AWNED, GLUMES GLABROUS, KERNEL SEMIHARD TO HARD—Continued.

Season, class, and identification number.	Kansas No.	C. I. No.	Varietal name.	Stem-rust infection.		Type of infection.		Remarks.		
				Seedlings.		Headed plants.				
				Number inoculated.	Number infected.	Number inoculated.	Number infected.		Seedlings.	Headed plants.
WINTER VARIETIES—continued.										
Common wheats—Continued.										
P1000.....	2435		Hickling.....	30	30	3	3	S	S	
P1003.....				30	28	3	3	S	S	
P1008.....	2428		Victoria.....	30	30	3	3	S	S	
P1013.....				30	29	3	3	S	S	
P1036.....	2412	2479	Romanella.....	30	27	3	3	S	S	
P1038.....	2422	2478	Fern or April.....	30	30	3	3	S	S	
P1066.....	2415	5879		c242	0	d6	0	R	R	
P1068.....	2414	5880		c212	0	d6	0	R	R	
P1078.....	2416	1543	Beloglina.....	30	29	6	6	S	S	
P1080.....				30	30			S	S	
P1111.....				30	27	3	3	S	S	
P1119.....				30	30	3	3	S	S	
P1128.....				30	30	3	3	S	S	
P1131.....				30	28	3	2	S	S	
P1134.....	2420	1436	Crimean.....	30	29	3	3	S	S	
P1161.....	2410	1787		30	30	3	3	S	S	
K34.....		5147	Nebraska No. 28.....	30	29	3	3	S	S	
K570.....		1558	Turkey.....	30	30	4	4	S	S	
K2048.....		5797	Alberta Red.....	30	30	3	3	S	S	
K2101.....		6213	Red Winter.....	30	30	3	3	S	S	
K2123.....		6214	Defiance Hard Winter.....	30	30	3	3	S	S	
K2413.....		6474		30	30	3	3	S	S	
C. I. 1442.....			Kharkof.....	30	30	3	3	S	S	
(?).....			Rieti.....	30	28	3	3	S	S	

Group 2.—AWNED, GLUMES GLABROUS, KERNEL SOFT.

WINTER VARIETIES.										
Common wheats:										
P638.....	2353		Binkel Club.....	30	13	3	3	S	S	Purple color.
P668.....	2365		Michigan Bronze.....	30	30	3	3	S	S	
K51.....		1981	Dietz Longberry.....	30	29	3	3	S	S	Do.
C. I. 1945.....			Lancaster.....	37	34	3	3	S	S	Do.
K36.....		2008	Mammoth Red.....	30	30	3	3	S	S	Do.
C. I. 1973.....			New Amber Longberry.....	30	30	3	3	S	S	
K47.....		2980	Stoner.....	30	30	3	3	S	S	Do.

Group 3.—AWNED, GLUMES PUBESCENT, KERNEL SOFT.

WINTER VARIETIES.										
Common wheats:										
P724.....	2392			30	29	3	3	S	S	
P1071.....				30	30	3	3	S	S	
K49.....		3277	Virginia.....	27	27	3	3	S	S	
(?).....			Velvet Chaff.....	30	30	3	3	S	S	(e)

e Since the completion of this work about 200 additional seedlings have been inoculated, with the same results.

d Since these inoculations were made, many additional culms have been inoculated, with the same results.

e Prominent flecks preceding uredinia.

TABLE 3.—Results of inoculating wheat varieties with stem rust in the greenhouse at the Kansas Agricultural Experiment Station at Manhattan, Kans., in the winter of 1916-17—Continued.

Group 4.—AWNLESS, GLUMES GLABROUS, KERNEL SOFT.

Season, class, and identification number.	Kan- sas No.	C. I. No.	Varietal name.	Stem-rust in- fection.		Type of in- fection.		Remarks.
				Seed- lings.	Headed plants.	Seedlings.	Hea ded plants.	
WINTER VARIETIES.								
Common wheats:								
P718.....	2389			30	30	3	3	Purple color. Do.
P739.....				30	30	3	3	
P740.....	2441	1535	Berdiansk.....	30	29	3	3	
P741.....				30	28	3	3	
P748.....				30	30	3	3	Do.
P765.....	2402			30	30	3	3	
P871.....				30	28	3	3	
P970.....	2403			30	30	6	6	
P980.....	2405		North Allerton...	30	17	3	3	Do.
P1064.....	2440	6218	Zimmerman.....	30	30	3	3	
P1092.....	2406	6216	Currell.....	30	30	3	3	
K39.....		1733	Damson Golden Chaff.	30	22	3	3	
K38.....		1744	Early Genesee Giant.	30	30	6	6	Do.
K42.....		1915	Purple Straw...	30	28	3	3	Do.
K40.....		1923	Fultz.....	90	90	3	3	Do.
K52.....		1969	Michigan Amber	37	36	3	3	Do.
C. I. 1979.....			Poole.....	30	30	3	3	Do.
K48.....		1980	Fultz-Mediterranean.	30	28	3	3	
K46.....		2997	Kofod.....	8	8	1	0	
(?).....		3326	Currell.....	30	30	1	1	

Group 5.—AWNLESS, GLUMES PUBESCENT.

WINTER VARIETIES.									
Common wheats:									
P1073.....	2408		Jones × Red Fife.....	30	30	3	3	S	S
K44.....		1933	Jones Winter Fife.....	30	25	2	2	S	S
K50.....			Mealy.....	30	30	3	3	S	S

Group 6.—AWNED, GLUMES PUBESCENT (TRITICUM VULGARE, T. DURUM, AND HYBRIDS).

SPRING VARIETIES.									
Common wheats:									
C. I. 2958.....			Preston (Minn. 188).....	30	30	3	3	S	S
H3 × 111.....	4783		Imillo × Preston.....	30	30	3	3	S	S
H4 × 942.10.....	4788		Kubanka × Preston.....	60	49	3	3	S	S
H5 × 223.....	4789		Kubanka × Bluestem.....	30	30	3	3	S	S

Group 7.—AWNED, GLUMES PUBESCENT.

SPRING VARIETY.									
Common wheat:									
C. I. 2442.....			Black Persian.....	30	30	2	2	R ₃	R ₃ (f)

f Uredinia numerous, very small.

TABLE 3.—Results of inoculating wheat varieties with stem rust in the greenhouses at the Kansas Agricultural Experiment Station at Manhattan, Kans., in the winter of 1916-17—Continued.

Group 8.—AWNLESS, GLUMES GLABROUS.

Season, class, and identification number.	Kansas No.	C. I. No.	Varietal name.	Stem-rust infection.				Type of infection.		Remarks.
				Seedlings.		Headed plants.		Seedlings.	Headed plants.	
				Number inoculated.	Number infected.	Number inoculated.	Number infected.			
SPRING VARIETY.										
Common wheats:										
C. I. 1517.....			Ghirka Spring ..	30	27	3	3	5	5	Purple color.
C. I. 3641.....			Marquis.....	30	30	3	3	5	5	
C. I. 2873.....			Glyndon Fife (Minn. No. 163).	30	30	3	3	5	5	

Group 9.—AWNLESS, GLUMES PUBESCENT.

SPRING VARIETIES.								
Common wheat:								
C. I. 2874.....			Haynes Blue-stem (Minn. 169).	30	30	3	3	

Group 10.—AWNED, GLUMES GLABROUS.

Durum wheats:											
H3X122A12.....			IumilloX Preston	30	29	2	2	R ₄ toS	R ₅	(g).	(h).
C. I. 1493.....			Arnautka.....	59	49			R ₅ toR ₄			
C. I. 1443.....			Gharnovka.....	30	30			R ₅ toR ₄			
C. I. 1513.....			Beloturka.....	30	0			R ₁ toR ₂		(i).	
C. I. 2094.....			Kubanka.....	29	21	6	6	R ₅ toR ₄	R ₂		
C. I. 3320.....			Monad.....	30	30			R ₅		(j).	
C. I. 3322.....			D-5.....	60	60			R ₄			
C. I. 5284.....			Acme.....	30	30	3	3	R ₅ toS	R ₅ toS		
C. I. 2228.....			Saragolla.....	29	29			R ₅ toS	R ₅ toS		

Group 11.—AWNED, GLUMES GLABROUS (WHITE).

Emmer and Einkorn:										
C. I. 1524.....			White Spring emmer.	30	17	3	3	R ₂	R ₅	(k).
C. I. 4781.....			do.....	30	30	3	3	R ₅ toR ₄	R ₁	(l).
C. I. 1526.....			Yaroslav emmer.	30	22	3	2	R ₃	R ₁	(m).
C. I. 4013.....			Khapli emmer.	30	30	10	10	R ₃	R ₃	
C. I. 3109.....			"Wild wheat" (T. hermonis).	16	16			S		
C. I. 2433.....			Common einkorn	30	30			S		
C. I. 2973.....			do.....	30	30			S		

g Uredinia uniformly small.

h Yellowish areas surround uredinia.

i No uredinia; extremely resistant.

j k Prominent yellowish areas surround uredinia.

k Heavy infection on mature plant.

l Yellow areas pronounced in some cases.

m Uredinia small; resistant.

All the varieties of winter wheat used can be placed in one of two classes: (1) Those which fail to show visible signs of uredinia and (2) those entirely susceptible. Those of the first group are designated by the symbol R, and those of the second group by S. Among the spring varieties there were different types of infection, these being represented by the symbols R_1 to R_5 and by S. Following is a description of the types of rust infection designated by the symbols:

EXPLANATION OF SYMBOLS USED.

R=Extremely resistant.

R_1 =No uredinia produced. Occasionally very small indefinite flecks, dead areas, or yellowish blotches occur. Signs of hypersensitiveness may be present.

R_2 =Very rarely the occurrence of minute uredinia (0.1 to 0.5 mm.); presence of flecks, dead areas, or blotches.

R_3 =Numerous minute to small uredinia (0.2 to 0.75 mm.); presence or absence of yellowish "islands" surrounding uredinia, or the occurrence of numerous yellow blotched areas surrounding or adjoining uredinia.

R_4 =Uredinia numerous, variable in size and number (0.2 to 0.4 mm.); flecked or blotched, yellow areas present; yellow areas adjoining uredinia.

R_5 =Uredinia apparently quite normal in size and shape, but presence of yellowish green areas surrounding or adjoining some uredinia indicative of slight resistance.

S=Showing ordinary susceptibility; uredinia large, normal, vigorous.

The inoculations of Kanred, P1066, and P1068 both in the seedling and in the heading stage produced consistent results, indicating extreme resistance.

The hard and soft wheat varieties did not differ strikingly in susceptibility, except in the case of Kanred, P1066, and P1068. The other hard red winter wheats apparently were as susceptible as the soft red winter wheats, although Leach (24) found a "decided correlation between the hardness and softness of wheat varieties and their relative susceptibility to *Puccinia graminis tritici-compacti*."

A greater variation occurred among the varieties of durum spring wheat. Beloturka (C. I. No. 1513) seemed to behave very much like the three resistant winter-wheat varieties, in that no uredinia were formed. In more recent work, however, in which the same strain of rust was used, Beloturka (C. I. No. 1513) occasionally has shown a few very small uredinia. Some of the durum varieties showed more or less uniformly the same type of infection (R_2 or R_4) as in the case of Kubanka (C. I. No. 2094), Arnautka (C. I. No. 1493), D-5 (C. I. No. 3322), and Gharnovka (C. I. No. 1443). A Poulard wheat (C. I. No. 4384) manifested a high degree of resistance. Among the emmers there was more or less similarity in the type of infection. The type of infection fluctuated in both of these groups, showing that various factors may affect the infection results. Two White Spring emmers (C. I. Nos. 1524 and 4781) showed the R_2 and R_4 types of infection, while another White Spring emmer (C. I. No.

1526) and Khapli emmer (C. I. No. 4013) seemed to show more consistently the type designated as R_3 . Khapli emmer (C. I. No. 4013) is the only variety of spring wheat so far studied that under all conditions seemed to exhibit a high degree of resistance in the field and in the greenhouse. Even this variety, however, may be classed at times as R_2 instead of R_3 . The seedlings of the so-called wild wheat of Palestine, *Triticum hermonis* Cook (C. I. No. 3109), really a form of emmer, all proved to be susceptible.

The purple color mentioned under "Remarks" occurred in some varieties and surrounded the uredinia. It does not appear consistently in any one variety. Environmental conditions seem to affect its production.

COMPARISON OF NURSERY AND GREENHOUSE RESULTS.

In general, the results of the greenhouse inoculations were similar to those produced under field conditions in the rust nursery. All of the winter-wheat varieties were found to be susceptible except Kanred, P1066, and P1068. Kansas No. 2390, which appeared to be partially resistant in the rust nursery, gave no evidence of being resistant in the greenhouse.

In the nursery, results on rust behavior usually are obtained on varieties in the heading stage, but in the greenhouse the seedling stage is most commonly used. Determining the resistance of varieties as seedlings is the most convenient method, particularly when a number of distinct biologic strains of rust are being used. It perhaps is the most severe test that can be given a variety and should always serve as a check on nursery results. The results thus obtained, however, scarcely can be considered as the sole criteria of the actual field resistance or susceptibility of a variety; in fact, plants showing certain effects when inoculated in the seedling stage in the greenhouse may respond very differently to the same rust when they are subjected to it in the heading stage under field conditions. No definite statements as to the cause of these differences can be made at this time. The same factors causing resistance or susceptibility may operate in all stages of growth, but the reaction of the host and parasite at various stages of development may be different.

It is possible that time of maturity may have an important influence on the extent of the rust on a given variety, but if the rust is epidemic before the plants reach the heading stage there can be no doubt as to the plants having been exposed to infection. The differences perhaps are due to complex factors in the developmental stages in a variety, which may cause a different response to rust infection. To whatever cause these differences in behavior in the seedling and heading stages may be due, the behavior of any variety

under field conditions is of first importance from the agronomic and plant-breeding viewpoint. The growing of wheat varieties in the rust nursery places them under conditions at least as severe as those to which a commercial field is subjected in a natural epidemic. Field tests must finally determine the value of any variety.

EVIDENCE OF SPECIFIC RUST RESISTANCE.

In the studies made of the resistant varieties, Kanred, P1066, and P1068, it was noted that their reaction to rust infection was entirely different from anything that had been observed in any other variety. Such varieties as Khapli emmer (C. I. No. 4013), White Spring emmers (C. I. Nos. 1524 and 1526 and Minnesota No. 1165), and the resistant durum Kubanka (C. I. No. 2094) and Arnautka (C. I. No. 1493) are known to show resistance in the seedling stage in the greenhouse as well as under field conditions. Their resistance in the seedling stage is shown by the formation of relatively small uredinia, surrounded by yellow or yellowish white areas, the occurrence of minute brown or yellowish dead areas, the presence of yellowish islands, or other characters generally regarded as indicative of resistance or hypersensitiveness. This evidence of resistance is illustrated in Plate XI. All the spring-wheat varieties which the writers have studied and which are classed as highly resistant show such reactions to rust infection, and almost always very distinct uredinia, though frequently small, are formed in inoculated seedlings of these varieties.

Kanred, P1066, and P1068 are unique in their behavior toward *Puccinia graminis tritici*, as hundreds of seedlings and of culms in the heading stage have been inoculated with this strain of rust and not a single uredinium ever has been observed. The entirely rust-free and unflecked inoculated leaves of Kanred and P1066 are illustrated in Plate XI, fig. 1, *A* and *B*. These varieties may be said to be immune¹⁰ from this particular stem rust, if it be assumed that the controlled conditions provided in the greenhouse are as favorable and that exposure to infection is as severe as under natural field conditions, and that seedling inoculations are as severe a test as can be given to a variety. They are certainly more strikingly resistant to *Puccinia graminis tritici* than any other varieties of common wheat (*Triticum vulgare*) which have been studied by the writers.

Because of this specific behavior these varieties have been used as differential hosts in separating certain biologic strains of stem rust of wheat. The inoculation studies with these varieties have been carried over a long period, including every month in the year,

¹⁰ The word "immune" is here used to mean freedom from any macroscopic evidence of rust infection or to designate the inability of the rust fungus to sporulate.

under various temperature conditions and at various stages of development of the plant. The work has been done by different persons at different agricultural experiment stations and always with the same results. The only visible evidence of infection in the seedling stage has been the occasional appearance of very indefinite, scarcely visible, whitish flecks, generally less than 0.1 millimeter in diameter. These indefinite flecks are not similar to the areas or flecks occurring on the seedlings of the resistant emmers and durumms (Pl. XI, fig. 2, *C*) and are very much less conspicuous. In this respect these three varieties of winter wheat are distinct in their behavior.

The behavior of Kanred, P1066, and P1068 in the nursery and field is not greatly different from that in the greenhouse. Table 1 shows that these varieties had very low percentages of stem-rust infection, varying in 1916 and 1917 from a trace to 10 per cent. In 1915 the percentages recorded were higher. In view of present knowledge of the existence of several distinct biologic strains of wheat-stem rusts (38, 39, 40, 41), this rather heavy infection very probably was due to the use of one or more biologic strains of stem rust similar to, if not identical with, the one recently described by the writers (30).

When mature culms of the three resistant varieties were inoculated in the greenhouse with cultures of *Puccinia graminis tritici*, a response on the part of the host to the rust infection was only occasionally visible. Slightly yellowish or brownish white minute dead areas were sometimes vaguely visible, indicating that infection had occurred but that the organism had ceased to develop.

The results reported in this bulletin establish the fact that Kanred and two other very similar pure lines of hard red winter wheat are resistant to certain biologic strains of black stem rust.

More recent studies (25, 30, 41) have shown that these varieties are not resistant to all the known strains of stem rust. Extensive field observations made in 1919 and 1920 have indicated, however, that Kanred is much less severely injured by most of the stem-rust strains occurring in Kansas than are Turkey and Kharkof, the other varieties commonly grown. Reports from Wisconsin, Alabama, Nebraska, New York, Illinois, Missouri, Iowa, California, and New South Wales (Australia) indicate that these three varieties have shown resistance to stem rust, while the Minnesota and the South Dakota agricultural experiment stations report them rather severely rusted, although in South Dakota Kanred showed less rust than Turkey. Because of the existence of distinct strains of stem rust it is probable that the behavior of these varieties will vary in different seasons and in various sections of the country.

RESISTANCE TO LEAF RUST.

Observations (31) made at Manhattan, Kans., during the 5-year period from 1915 to 1919, inclusive, and field notes recorded in all sections of the State in 1919, 1920, and 1921 show that these three pure lines of Crimean wheat are remarkably resistant also to leaf rust (*Puccinia triticina*) as it occurs in Kansas. Mains and Jackson (27) also have found these three varieties to be very resistant to leaf rust under field conditions and where the plants were approaching the heading stage. According to these workers, however, seedlings of these varieties do not prove to be resistant to leaf rust when inoculated and maintained under greenhouse conditions.

The resistance to leaf rust has been manifested also in experimental field sowings made in the States of Alabama, California, Missouri, North Carolina, North Dakota, Oregon, South Dakota, Tennessee, Texas, Virginia, and Wisconsin, and also in New South Wales, Australia. Present knowledge of the leaf-rust problem and the records from a wide range of sowings subjected to severe epidemics of leaf rust indicate rather definitely that Kanred, P1066, and P1068 will maintain this high degree of resistance under a wide range of conditions. It should not be supposed, however, that the resistance of these varieties to leaf rust will be absolute under all conditions or in the presence of all the biologic strains of leaf rust which may exist.

AGRONOMIC VALUE OF KANRED WHEAT.

Kanred wheat presents a unique combination of desirable agronomic characters, a fact which is of even greater significance than its resistance to rusts. Jardine (19) described the origin and history of Kanred wheat and called attention to its higher yield, earliness, and cold resistance.

Call and Salmon (6) state that "at Manhattan, the average production of Kanred has been 4.5 bushels per acre more than Turkey and 4.7 bushels more than Kharkof." It has outyielded these varieties in every season but one and in that season (1914) practically equaled the others. Salmon (36) presents further experimental data on the superiority of Kanred and gives statements regarding the value of Kanred from a large number of farmers who have grown the new variety.

It is estimated that at least 1,500,000 acres were sown to Kanred wheat in Kansas in the fall of 1920, and it is expected that within a few years this variety will occupy a large percentage of the hard winter-wheat acreage of Kansas. If the area sown to Kanred should reach 7,000,000 acres and the yield should be increased 3 bushels per acre, with wheat selling at \$1 per bushel, other factors remaining unchanged, the annual value added to the Kansas wheat

crop as a result of the production of Kanred wheat would be \$21,000,000. A statement of the agronomic value of this variety will be found in Circular 194 of the United States Department of Agriculture.

Although the problem of breeding wheat for resistance to stem rust has been greatly complicated by recent discoveries of a number of distinct biologic strains of rust which are present in the several grain-growing regions, Kanred wheat in the future probably will prove of great value as a parental variety in crosses, for it certainly contains factors for resistance to some strains of leaf rust and stem rust. There is good evidence that these factors are transmitted in wheat hybrids in the same general way as the factors for other characters. Kanred wheat is being used by the Tennessee Agricultural Experiment Station as the rust-resistant parent in a series of crosses with adapted varieties of soft red winter wheat, in the hope of producing varieties of soft red winter wheat resistant to leaf rust and otherwise equal to the best varieties now being grown, which are often severely damaged by leaf rust. Kanred also has been used at the Kansas and Minnesota Agricultural Experiment Stations as a parent in a large number of crosses. It is too early to make any predictions as to the value of any of these hybrids, although several of them appear promising.

SUMMARY.

(1) Field experiments to determine the resistance to black stem rust (*Puccinia graminis tritici*) of about 100 varieties and strains of winter wheat, many of them pure-line selections, and of a few varieties of spring wheat, were conducted in a rust nursery at Manhattan, Kans., in 1915, 1916, and 1917. Greenhouse experiments were conducted during the winter of 1916-17, using the same varieties. Special methods were developed for producing rust epidemics under the prevailing climatic conditions of Kansas.

(2) In the rust nursery severe epidemics were produced each season, and the percentage of rust infection probably represented the maximum rust attack which the varieties would encounter under field conditions.

(3) All the winter-wheat varieties grown were found to be susceptible to stem rust except Kanred and two very similar pure-line selections, P1066 and P1068. These three varieties were found to be resistant. Another pure-line strain, Kansas No. 2390, gave evidence of being partially resistant.

(4) Plumpness of kernels usually is reduced by severe rust attack. The three resistant varieties produced grain of good quality in 1916 and 1917, when other varieties grown under the same conditions but much more severely rusted produced very badly shrunk kernels.

(5) Several varieties of spring wheat proved rust resistant under the conditions of these experiments, though the Black Persian was the only spring-wheat variety of the common or bread-wheat group (*Triticum vulgare*) which was found to be resistant. Of the varieties of durum or macaroni wheat (*Triticum durum*), Beloturka (C. I. No. 1513), Iumillo (C. I. No. 1736), Kubanka (C. I. No. 2094), Monad (D-1), and Pentad (D-5) showed definite signs of resistance to stem rust. A hybrid of Iumillo $\times$ Preston, resembling the durum parent, also was found to be rust resistant. All of the strains of emmer and einkorn grown gave some evidence of resistance.

(6) In the greenhouse experiments the plants were studied for rust resistance at two stages of growth, viz, as seedlings and at the time of heading. The results were very similar to those in the field experiments. All the winter-wheat varieties were susceptible except three—Kanred, P1066, and P1068. Kansas No. 2390, which appeared to be somewhat resistant in the field, showed no evidence of resistance at either stage of growth in the greenhouse. Most of the spring-wheat varieties which the field experiments had shown to be resistant also gave more or less evidence of resistance under greenhouse conditions. This was not true, however, of einkorn.

(7) Although the results obtained in the field and those in the greenhouse agree fairly well, final conclusions as to rust resistance of a variety should not be drawn from greenhouse tests alone. The combined evidence from nursery experiments and inoculations of seedlings and of plants in the heading stage under greenhouse conditions is much more likely to agree with actual field trials, which must always be the final test of the practical value of any variety.

(8) The behavior of the rust parasite on the inoculated plants of the three resistant varieties—Kanred, P1066, and P1068—seems to be different from that in other varieties described as resistant. In most other varieties prominent flecks are nearly always present in 8 to 12 days after inoculation, and most frequently small uredinia are produced. In these three varieties, however, flecks are very rarely visible, and in no instance have even the most minute uredinia been observed.

(9) Reports from Alabama, California, Illinois, Iowa, Missouri, Nebraska, New York, Wisconsin, and New South Wales indicate that these three varieties are resistant to stem rust; but Minnesota and South Dakota report them rather severely attacked by stem rust. The occurrence of distinct strains of stem rust complicates the problem of predicting what their behavior may be during different seasons. Present knowledge of the distribution of stem-rust strains and whether they occur each season in definite regions is so limited that the resistance or susceptibility of these wheats in any region may differ from season to season.

(10) The very light infection of leaf rust in sowings made in Alabama, Arkansas, California, Missouri, North Carolina, North Dakota, Oregon, South Dakota, Tennessee, Texas, Virginia, and Wisconsin, and in New South Wales has proved that these three varieties are extremely resistant to leaf rust also. Present knowledge of the leaf-rust problem indicates rather definitely that these varieties will maintain this high degree of resistance under a wide range of conditions.

(11) Kanred, one of the three rust-resistant pure lines, has an unusual combination of desirable characters. In Kansas it yields from 3 to 5 bushels more per acre than either Turkey or Kharkof, the varieties commonly grown. It ripens a little earlier, thus escaping some of the damage from drought and hot winds during the ripening period. Kanred also seems to be more winter hardy in Kansas than other varieties and survives the severe winters with less loss from winterkilling. In milling and baking quality it apparently is equal to Turkey and Kharkof, varieties of hard red winter wheat which have established a world-wide reputation for quality.

(12) Experiments and the experience of large numbers of farmers have shown that Kanred is adapted to other sections of the hard winter-wheat area, and it is now rapidly being introduced and widely grown in Oklahoma, Texas, Nebraska, eastern Colorado, and some other States.

(13) Kanred wheat is believed to have considerable potential value also as a parental variety to be used by plant breeders in combining its rust resistance and other valuable characters with those of the varieties of other classes of wheat adapted to the several wheat-growing districts.

LITERATURE CITED.

- (1) ANDERSON, H. C. L.
1890. Rust in wheat. Experiments and their objects. *In Agr. Gaz. N. S. Wales*, v. 1, pt. 1, p. 81-90, illus.
- (2) BIFFEN, R. H.
1907. Studies in the inheritance of disease resistance. *In Jour. Agr. Sci.*, v. 2, pt. 2, p. 109-128.
- (3) BOLLEY, H. L.
1889. Wheat rust. *Ind. Agr. Exp. Sta. Bul.* 26, 19 p., 9 fig.
- (4) 1905. Experiments and studies upon wheat. *In No. Dak. Agr. Exp. Sta. 15th Ann. Rpt.* 1904, p. 34-54, 1-5 fig. (on pl.).
- (5) 1909. Some results and observations noted in breeding cereals in a specially prepared disease garden. *In Amer. Breeders' Assoc. Rpt.*, v. 5 (1908), p. 177-182.
- (6) CALL, L. E., AND SALMON, S. C.
1918. Growing wheat in Kansas. *Kans. Agr. Exp. Sta. Bul.* 219, 51 p., 11 fig.
- (7) CARLETON, MARK ALFRED.
1903. Culture methods with Uredineæ. *In Jour. Appl. Micros. and Lab. Methods*, v. 6, no. 1, p. 2109-2114.
- (8) 1905. Lessons from the grain-rust epidemic of 1904. *U. S. Dept. Agr., Farmers' Bul.* 219, 24 p., 6 fig.
- (9) ——— and CHAMBERLAIN, JOSEPH S.
1904. The commercial status of durum wheat. *U. S. Dept. Agr., Bur. Plant Indus. Bul.* 70, 70 p., 1 fig., 5 pl.
- (10) CLARK, J. ALLEN, MARTIN, JOHN H., and SMITH, RALPH W.
1920. Varietal experiments with spring wheat on the northern Great Plains. *U. S. Dept. Agr. Bul.* 878, 48 p., 2 fig., 3 pl. Publications on cereals in the Great Plains area, p. 48.
- (11) ERIKSSON, JAKOB, and HENNING, ERNST.
1896. Die Getreideroste. Ihre Geschichte und Natur sowie Massregeln gegen dieselben. vii, 463 p., 5 fig., 13 col. pl., 1 col. tab. Stockholm. Litteraturverzeichnis, p. 446-457.
- (12) FREEMAN, E. M., and JOHNSON, EDWARD C.
1911. The rusts of grains in the United States. *U. S. Dept. Agr., Bur. Plant Indus. Bul.* 216, 87 p., 2 fig., 1 pl. Bibliography, p. 79-82.
- (13) HAYES, H. K., PARKER, JOHN H., and KURTZWELL, CARL.
1920. Genetics of rust resistance in crosses of varieties of *Triticum vulgare* with varieties of *T. durum* and *T. dicoccum*. *In Jour. Agr. Research*, v. 19, no. 11, p. 523-542, pl. 97-102. Literature cited, p. 541-542.
- (14) HENNING, ERNST.
1894. Några ord om olika predisposition för rost å säd. *In K. Landtbr. Akad. Handl. och Tidskr.*, årg. 33, p. 205-217.
- (15) HENSLOW, J. S.
1841. Report on the diseases of wheat. *In Jour. Roy. Agr. Soc. England*, v. 2, p. 1-25.

- (16) HITCHCOCK, A. S., and CARLETON, M. A.
1893. Preliminary report on rusts of grain. *Kans. Agr. Exp. Sta. Bul.* 38, 14 p., 3 pl.
- (17) 1894. Second report on rusts of grain. *Kans. Agr. Exp. Sta. Bul.* 46, 9 p.
- (18) HUTCHESON, T. B., and QUANTZ, K. E.
1917. The effect of greenhouse temperatures on the growth of small grains.
In Jour. Amer. Soc. Agron., v. 9, no. 1, p. 17-21, 1 fig., 2 pl.
- (19) JARDINE, W. M.
1917. A new wheat for Kansas. *In Jour. Amer. Soc. Agron.*, v. 9, no. 6, p. 257-266.
- (20) JOHNSON, EDWARD C.
1911. Methods in breeding cereals for rust resistance. *In Proc. Amer. Soc. Agron.*, v. 2 (1910), p. 76-80.
- (21) 1912. Cardinal temperatures for the germination of uredospores of cereal rusts. (Abstract.) *In Phytopathology*, v. 2, no. 1. p. 47.
- (22) KELLERMAN, W. A.
1903. Uredineous infection experiments in 1902. *In Jour. Mycol.*, v. 9, no. 65, p. 6-13.
- (23) LA COUR, J. C.
1863. Sygdommene i kornet og midlerne derimod. *In Tidsskr. Landøkon.*, Række 3, Bd. 11, p. 249-264.
- (24) LEACH, JULIAN G.
1919. The parasitism of *Puccinia graminis tritici* Erikss. and Henn. and *Puccinia graminis tritici-compacti* Stak. and Piem. *In Phytopathology*, v. 9, no. 2, p. 59-88, pl. 4-6.
- (25) LEVINE, M. N., and STAKMAN, E. C.
1918. A third biologic form of *Puccinia graminis* on wheat. *In Jour. Agr. Research*, v. 13, no. 12, p. 651-654.
- (26) LITTLE, W. C.
1883. Report on wheat-mildew. *Jour. Roy. Agr. Soc. England*, ser. 2, v. 19, p. 634-691.
- (27) MAINS, E. B., and JACKSON, H. S.
1921. Two strains of *Puccinia triticea* on wheat in the United States. (Abstract.) *In Phytopathology*, v. 11, no. 1, p. 40.
- (28) MELCHERS, LEO E.
1915. A way of obtaining an abundance of large uredinia from artificial culture. *In Phytopathology*, v. 5, no. 4, p. 236-237.
- (29) ——— and PARKER, JOHN H.
1918. Three varieties of hard red winter wheat resistant to stem rust. (Abstract.) *In Phytopathology*, v. 8, no. 2, p. 79.
- (30) 1918. Another strain of *Puccinia graminis*. *Kans. Agr. Exp. Sta. Circ.* 68, 4 p.
- (31) 1920. Three winter wheat varieties resistant to leaf rust in Kansas. *In Phytopathology*, v. 10, no. 3, p. 164-171, 3 fig. Literature cited, p. 171.
- (32) MELHUS, I. E., and DURRELL, L. W.
1919. Studies on the crown rust of oats. *Iowa Agr. Exp. Sta. Research Bul.* 49, p. 115-144, 6 fig. Bibliography, p. 143-144.
- (33) NILSSON-EHLE, H.
1911. Kreuzungsuntersuchungen an Hafer und Weizen. II. *In Lunds Univ. Årsskr.*, n. f., afd. 2, bd. 7, nr. 6, 84 p. Literaturverzeichnis zu der Einleitung, p. 20.

- (34) PARKER, JOHN H.
1918. Greenhouse experiments on the rust resistance of oat varieties. U. S. Dept. Agr. Bul. 629, 16 p., 2 fig., 3 pl. Literature cited, p. 16.
- (35) RUST IN WHEAT CONFERENCE.
1891-92. Report of the proceedings, 2d-3d session, 1891-92. Sydney (N. S. Wales), Adelaide (S. Australia).
- (36) SALMON, S. C.
1919. Establishing Kanred wheat in Kansas. Kans. Agr. Exp. Sta. Circ. 74, 16 p., 7 fig.
- (37) STAKMAN, E. C.
1914. A study in cereal rusts. Physiological races. Minn. Agr. Exp. Sta. Bul. 138, 56 p., 9 pl. Bibliography, p. 50-54.
- (38) ——— and HOERNER, G. R.
1918. The occurrence of *Puccinia graminis tritici-compacti* in the southern United States. *In* *Phytopathology*, v. 8, no. 4, p. 141-149, 2 fig.
- (39) ——— LEVINE, M. N., and LEACH, J. G.
1919. New biologic forms of *Puccinia graminis*. [Preliminary paper.] *In* *Jour. Agr. Research*, v. 16, no. 3, p. 103-105.
- (40) ——— and PIEMEISEL, F. J.
1917. Biologic forms of *Puccinia graminis* on cereals and grasses. *In* *Jour. Agr. Research*, v. 10, no. 9, p. 429-496, pl. 53-59.
- (41) UNITED STATES DEPARTMENT OF AGRICULTURE.
1920. Kanred wheat epoch-making for Kansas ... *In* U. S. Dept. Agr. Weekly News Letter, v. 8, no. 6, p. 6.
- (42) WALDRON, L. R., and CLARK, J. A.
1919. Kota, a rust-resisting variety of common spring wheat. *In* *Jour. Amer. Soc. Agron.*, v. 11, no. 5, p. 187-195, pl. 7.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
20 CENTS PER COPY



UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1047

Contribution from the Office of Farm Management and
Farm Economics

G. W. FORSTER, Acting Chief



Washington, D. C.

December 28, 1921

FARM MORTGAGE LOANS BY BANKS, INSURANCE COMPANIES, AND OTHER AGENCIES.

By V. N. VALGREN, *Associate Agricultural Economist*, and ELMER E. ENGELBERT,
Junior Economist in Farm Finance.

CONTENTS.

	Page.		Page.
Need of more complete data.....	1	Other sources.....	5
Nature and comparability of data.....	2	Basis of figures on loans by banks.....	6
Loans by life insurance companies.....	4	First and second mortgage loans by banks..	9
Loans by Federal Land Bank System.....	4	Interest rates on farm mortgage loans.....	10
Loans from State funds or agencies.....	5	Term of loan and method of repayment.....	21
Loans by farm mortgage bankers.....	5	Conclusion.....	21

The financial difficulties experienced by farmers during the year 1921 have led to renewed interest in the problems of rural credit, and attempts have recently been made by the Department of Agriculture to gather significant data on this subject. The specific object of the study, which was made by means of questionnaires and correspondence, was to ascertain the amount of farm credit available from various sources, the cost of such credit to the farmer, the term for which loans are available, and the method of repayment provided for. The facts relating to farm mortgage credit, as disclosed in this study, will be found in condensed form on the following pages.

NEED OF MORE COMPLETE DATA.

The information available concerning the amount and sources of farm mortgage loans in the United States is fragmentary. The censuses of 1890, 1900, 1910, and 1920 in each case called for certain information regarding mortgage loans on farms operated by full owners. According to the final reports for the census of 1920, mortgage indebtedness on farms so operated amounted to \$4,003,-767,192, as against \$1,726,172,851 in 1910. The value of the farms operated by full owners has also been made public, as well as the

value of all farms in the United States. The figures for estimated total farm mortgage indebtedness as given in the first column of Table 1 are based on the assumption that in each State all farms are on the average mortgaged to the same percentage of their value as are the owner-operated farms for which data are available. This is a somewhat bold assumption, as no comprehensive study has been made of the relative amount of indebtedness on owner-operated farms as compared with that on farms of other tenures. It seems probable that these figures are somewhat high for many States, or, in other words, that they represent the maximum rather than the actual amount.

Information concerning the sources of farm mortgage loans, so far as present holders of mortgages represent such sources, is no more complete than the figures on total mortgages outstanding. The estimated totals of farm mortgages held by banks, as shown in the second column of Table 1, also involve certain assumptions which expose them to possible error. The method followed in arriving at these estimates will be outlined on a later page.

NATURE AND COMPARABILITY OF DATA.

The figures in Table 1 on loans held by insurance companies, by the Federal and joint-stock land banks, by State agencies, and by farm mortgage bankers, respectively, represent actually reported figures only. The amounts reported for the land banks are official and complete.

The figures given for the amounts and percentages of farm loans held by the various agencies, although not exactly comparable, are, with certain explanations, sufficiently so to warrant their being presented together. The figures representing bank loans are distributed on the basis of the location of the banks rather than of the loans, whereas for the other agencies the location of the mortgaged property determines the allocation. An examination, therefore, of the amounts and percentages of loans held by the various agencies will disclose that in some States the banks held more than 100 per cent of the estimated total farm mortgages for the States in which they were located. This is due, of course, to the fact that the banks of these States had invested a considerable portion of their funds in farm loans in other States, chiefly certain States in the central section where land values are considered well established, and the rates of interest are nevertheless appreciably higher than in the States in which these banks are located. As a general rule, however, the farm mortgage loans held by banks are on land located in or near the regular business territory of the banks.

TABLE 1.—*Estimated amount and partial sources of farm mortgage loans, 1920, by States (in millions of dollars).*

Geographic division and State.	Estimated total farm mortgage debt.	Farm mortgages held by—									
		Banks.		Insurance companies.		Land banks. ^a		State agencies.		Mortgage bankers.	
		Amount.	Per cent.	Amount.	Per cent.	Amount.	Per cent.	Amount.	Per cent.	Amount.	Per cent.
United States.....	8,556.8	1,447.5	17	1,214.7	14	5435.1	5	95.2	1	253.3	3
New England.....	124.8	93.7	75	1.9	2	7.0	6	.5	(d)	.....	.....
Maine.....	20.9	5.4	26	(c)	.....	2.0	10	(c)	.....	.....	.....
New Hampshire.....	8.6	8.9	103	.....	.....	.4	5	.....	.....	.....	.....
Vermont.....	31.5	65.3	207	(c)	.....	1.0	3	.....	.....	.....	.....
Massachusetts.....	34.7	7.1	20	(c)	.....	1.9	5	.....	.....	.....	.....
Rhode Island.....	2.5	.3	12	.....	.....	.2	8	.....	.....	.....	.....
Connecticut.....	26.5	6.7	25	1.9	7	1.5	6	.5	2	.....	.....
Middle Atlantic.....	431.6	34.1	8	.5	(d)	10.0	2	.....	.....	.....	.....
New York.....	241.5	24.0	10	.3	(d)	5.4	2	.....	.....	.....	.....
New Jersey.....	42.7	1.0	2	(c)	.....	1.0	2	.....	.....	.....	.....
Pennsylvania.....	147.4	9.1	6	.1	(d)	3.5	2	.....	.....	.....	.....
East North Central.....	1,862.0	335.1	18	165.3	9	53.7	3	6.7	(d)	17.8	1
Ohio.....	246.6	51.9	21	23.3	9	4.3	2	.....	.....	1.8	1
Indiana.....	247.3	78.9	32	70.7	29	18.9	8	6.5	3	16.0	6
Illinois.....	640.5	106.0	17	64.3	10	17.2	3	.2	(d)	(c)	.....
Michigan.....	238.1	32.6	14	1.6	1	6.1	3	.....	.....	.....	.....
Wisconsin.....	489.5	65.7	13	5.5	1	7.3	1	.....	.....	.....	.....
West North Central.....	3,435.0	531.2	15	737.6	21	153.3	4	51.3	1	39.0	1
Minnesota.....	481.5	124.9	26	76.9	16	21.3	4	.....	.....	4.5	1
Iowa.....	1,200.2	213.3	18	285.7	24	47.2	4	4.8	(d)	11.1	1
Missouri.....	405.2	75.1	19	97.4	24	15.6	4	.....	.....	.5	(d)
North Dakota.....	280.3	27.1	10	28.8	10	20.7	7	9.4	3	3.3	1
South Dakota.....	298.5	22.1	7	59.4	20	9.6	3	37.1	12	6.7	2
Nebraska.....	451.6	35.3	8	91.2	20	20.6	5	.....	.....	5.6	1
Kansas.....	317.7	33.4	11	98.2	31	18.4	6	.....	.....	7.2	2
South Atlantic.....	264.6	94.0	26	46.6	13	33.4	9	.....	.....	8.7	2
Delaware.....	9.8	2.0	20	.2	2	.1	1	.....	.....	.....	.....
Maryland.....	51.6	5.6	11	.4	1	1.0	2	.....	.....	.....	.....
Dist. of Columbia.....	.3	1.2	400	.....	.....	.....	.....	.....	.....	.....	.....
Virginia.....	62.9	13.5	21	1.2	2	8.6	14	.....	.....	.....	.....
West Virginia.....	15.8	4.3	27	.1	1	3.5	22	.....	.....	.....	.....
North Carolina.....	59.5	24.7	42	7.0	12	6.3	11	.....	.....	.....	.....
South Carolina.....	54.5	17.2	32	6.3	12	6.3	12	.....	.....	(c)	.....
Georgia.....	90.7	21.2	23	30.1	33	4.4	5	.....	.....	8.1	9
Florida.....	19.6	4.3	22	1.3	7	3.2	16	.....	.....	.6	3
East South Central.....	323.0	101.1	31	51.7	16	33.4	10	.....	.....	.8	(d)
Kentucky.....	104.0	25.9	25	12.6	12	5.5	5	.....	.....	(c)	.....
Tennessee.....	83.9	19.3	23	17.4	21	7.5	9	.....	.....	.....	.....
Alabama.....	56.4	12.6	22	8.9	16	8.2	15	.....	.....	.6	1
Mississippi.....	78.6	43.3	55	12.8	16	12.2	16	.....	.....	.1	(d)
West South Central.....	748.2	73.3	10	154.0	21	68.0	9	16.1	2	33.3	4
Arkansas.....	81.5	22.2	27	12.9	16	10.8	13	.....	.....	2.5	3
Louisiana.....	42.7	26.7	63	3.0	7	5.6	13	.....	.....	.3	1
Oklahoma.....	201.4	8.7	4	48.0	24	6.6	3	16.1	8	11.3	6
Texas.....	422.6	15.6	4	90.2	21	44.9	11	.....	.....	19.2	5
Mountain.....	551.5	55.9	10	30.2	5	40.1	7	13.5	2	28.2	5
Montana.....	154.6	19.3	12	11.4	7	12.2	8	4.4	3	10.5	7
Idaho.....	117.1	6.0	5	9.0	8	10.7	9	3.3	3	7.5	6
Wyoming.....	35.0	7.1	20	.8	2	1.4	4	.....	.....	1.5	4
Colorado.....	141.9	6.1	4	3.0	2	5.7	4	.4	(d)	7.6	5
New Mexico.....	23.7	1.2	5	3.2	14	3.4	14	.....	.....	1.0	4
Arizona.....	31.9	3.4	11	1.0	3	.7	2	1.5	5	.....	.....
Utah.....	35.6	9.9	28	1.5	4	5.9	17	3.9	11	.....	.....
Nevada.....	11.8	2.9	25	.3	3	.2	2	.....	.....	.....	.....
Pacific.....	716.1	129.0	18	26.9	4	36.1	5	7.1	1	9.4	1
Washington.....	134.9	9.3	7	8.4	6	12.1	9	.....	.....	5.5	4
Oregon.....	103.0	5.4	5	5.2	5	11.7	11	7.1	7	3.9	4
California.....	478.3	114.3	24	13.3	3	12.2	3	.....	.....	.....	.....

^a Including both Federal and joint-stock land banks.^b Including \$7,459,243 not allocated by States, repaid on principal.^c Indicates less than \$100,000.^d Less than one-half of 1 per cent.

LOANS BY LIFE INSURANCE COMPANIES.

The figures presented for life insurance companies are based on replies received from 216 companies out of a total number of 266. The 216 companies reporting had admitted assets of \$6,539,537,868, representing 96.3 per cent of the assets of the total number of life insurance companies as reported in the Insurance Yearbook of 1920. Only 29 out of the 216 companies reported no farm mortgage loans. Assuming the farm mortgages held by the 50 companies not reporting to be the same percentage of their assets as that obtained for reporting companies, the total amount of farm mortgage loans held by all life insurance companies would be \$1,256,225,217, or approximately \$42,000,000 more than was actually reported and shown in the table. The total real estate loans of the 216 companies which reported amounted to \$2,024,745,646. Farm mortgage loans, therefore, constituted 60 per cent of all real estate loans of these companies and 18.6 per cent of their admitted assets. In 1914, farm mortgage loans constituted only 39.7 per cent of total real estate loans and 13.3 per cent of admitted assets, whereas in 1916 the corresponding figures were 46.6 per cent and 15.3 per cent, respectively.¹ The increased percentage of assets invested in farm mortgages by life insurance companies is particularly striking in view of the fact that the percentage of total admitted assets represented by real estate loans of all kinds has decreased from 34.6 per cent in 1914 to 34.2 per cent in 1916¹ and to 31 per cent in 1920. The figures in the table indicate that Iowa has 23.5 per cent of all farm mortgage loans by life insurance companies, which is approximately as much as was reported for the three next highest States, namely, Kansas, Missouri, and Nebraska, each of which had between ninety and a hundred millions of such loans.

The larger life insurance companies as a rule maintain their own investment departments and employ special loan agents or correspondents. Others rely for their mortgage loans largely on banks and mortgage brokers.

LOANS BY FEDERAL LAND BANK SYSTEM.

As has been previously stated, the figures given for the land banks are official, and comprise those for both the Federal and joint-stock land banks. It will be observed that in spite of adverse conditions, these institutions are now carrying 10 or more per cent of the estimated farm mortgage loans in 14 States. In general, the ratios of land bank loans to the estimated total farm mortgage debt are highest in the Southern and Western States, where farm mortgage credit has hitherto been particularly inadequate.

¹ "Life Insurance Farm Loan Investments in War Time," by Geo. T. Wight, Secretary and Manager, Association of Life Insurance Presidents.

LOANS FROM STATE FUNDS OR AGENCIES.

Considering the United States as a whole, the credit extended by so-called State agencies is rather insignificant. In a few of the States, however, especially South Dakota, Utah, Oklahoma, and Oregon, this source of credit has been of material aid to the farmers. In South Dakota and Oregon, systems are in operation under which State bonds are issued on the basis of first mortgages in a manner resembling that followed by the Federal Farm Loan System. In South Dakota 29 of the 37 million dollars of State loans indicated are from its rural credit system and the remainder from the public-school fund of the State. In Oklahoma bonds may be issued on the basis of second mortgages accepted under the so-called home ownership law. In the remaining 10 States the loans indicated for State agencies are from funds which originated chiefly through the sale of land belonging to the State schools or charitable institutions. In February of this year Wyoming enacted a rural credit law which authorizes loans to farmers on first mortgages from the common school permanent land fund. Although the system has not been in operation sufficiently long to permit the extension of much credit, the law provides that such loans may be made for a total not exceeding \$1,000,000.

LOANS BY FARM MORTGAGE BANKERS.

The figures presented for the mortgage bankers are by far the most fragmentary of all. Questionnaires were sent to 132 of the more important farm mortgage bankers in the various States whose names and addresses were available. Sixty-four companies replied. In addition to the \$253,313,656 of farm mortgages reported as held, \$82,364,385 of farm mortgages had been sold to investors during the year. As might be expected, these companies are located chiefly in the larger cities of agricultural sections and place loans either in their own or in nearby States. These firms, therefore, constitute an important factor in meeting the demand for farm mortgage securities by investors, and thereby materially enlarge the source of such loans to the farmer.

OTHER SOURCES.

The five sources discussed above account for only about 40 per cent of the farm mortgage credit as indicated by the estimated mortgage debt. Undoubtedly, former owners and private investors constitute two of the most important sources for which no figures are available. In certain sections of the country it is a common practice for the seller to take a mortgage on the land as security for a liberal portion of the sale price. When a mortgage already exists

against the land it is frequently assumed by the purchaser, or a new first mortgage may be placed by him with some financial institution, the former owner accepting a second mortgage for his interest in the land. A very large percentage of the second mortgages on farm land are, therefore, held by former owners, as well as a considerable percentage of the first mortgages.

BASIS OF FIGURES ON LOANS BY BANKS.

Table 2 summarizes the actual returns from the questionnaire to banks. These figures, together with data from the comptroller's report, constitute the basis of the estimated total farm mortgage loans by banks, as given in Table 1. For the United States as a whole, 45 per cent of the banks reported. The lowest percentage of return was 27.5 per cent, from North Carolina, and the highest, 72 per cent, from Massachusetts.

In estimating the total farm mortgage loans held by banks, the figures for national banks and those for "banks other than national" were for each State tabulated and calculated separately.²

In general, the loans held by commercial banks originated with them. The country banks especially are instrumental in placing farm mortgage loans with insurance companies, as well as with savings banks, trust companies, and mortgage bankers in the larger cities. In some cases, these country banks sell mortgages which they already own, but more often they act merely as agents or correspondents either for the farmer or for the investor and may or may not assume liability to the investor.

² It was assumed in the case of each State, first, that the percentage obtained by dividing the total loans and discounts of each class of banks which replied to our questionnaire into the total loans and discounts of such of these banks as reported some farm mortgage loans applied also to the loans and discounts of banks of the same class which did not reply to the questionnaire. Secondly, it was assumed that the percentage of loans and discounts represented by farm mortgage loans in the case of the banks reporting some farm mortgage loans held also for the part of the loans and discounts not reported, but which, according to the first calculation, were composed of some farm mortgage loans. In the State of Missouri, for instance, the total loans reported by banks other than national were \$172,370,019, and the loans reported by banks whose loans, in part, represented farm mortgage loans were \$119,772,263 or 69.5 per cent of the total. Furthermore, of the total loans reported by the banks the loans of which were, in part, farm mortgage loans, \$21,683,921, or 18.1 per cent were farm mortgage loans. By applying the first of these percentages, 69.5 per cent, to \$587,691,000, which was the total amount of loans and discounts of banks other than national reported for the State by the Comptroller of the Currency, a total of \$408,445,245 was obtained which represented the loans and discounts of banks having some farm mortgage loans; and by applying the second percentage, or 18.1 per cent, to the last named sum, a total of \$73,989,362 was obtained for farm mortgage loans. A similar computation was then made for the amount of farm mortgage loans held by national banks, and the resulting figure was added to those obtained above, giving a total of farm mortgage loans held by all banks in Missouri amounting to \$75,093,027.

TABLE 2.—Number of banks replying to the questionnaire and amount of farm mortgage loans actually reported.

Geographic division and State.	Number of banks (Comptroller's report).			Number of banks reporting.			Amount reported.		
	All classes.	National.	Other than national.	All classes.	National.	Other than national.	All classes.	National.	Other than national.
United States.....	30,178	8,124	22,054	13,540	4,206	9,334	\$602,100,237	\$65,937,830	\$536,162,407
New England.....	1,129	411	718	661	234	427	41,645,901	726,665	40,919,236
Maine.....	161	63	98	82	28	54	2,201,395	132,950	2,068,445
New Hampshire.....	126	56	70	51	22	29	7,051,572	40,221	7,011,351
Vermont.....	108	49	59	41	17	24	24,001,290	447,916	23,553,374
Massachusetts.....	466	160	306	335	119	216	4,865,972	62,388	4,803,584
Rhode Island.....	48	17	31	33	11	22	94,050	-----	94,050
Connecticut.....	220	66	154	119	37	82	3,431,622	43,190	3,388,432
Middle Atlantic.....	3,009	1,573	1,436	1,709	965	744	19,259,776	2,711,671	16,548,105
New York.....	1,063	498	565	620	302	318	13,847,234	1,083,111	12,764,123
New Jersey.....	393	217	176	251	139	112	495,475	176,125	319,350
Pennsylvania.....	1,553	858	695	838	524	314	4,917,067	1,452,435	3,464,632
East North Central.....	5,507	1,386	4,121	2,645	737	1,908	153,661,260	16,397,663	137,263,597
Ohio.....	1,153	378	775	544	190	354	23,583,489	3,455,189	20,128,300
Indiana.....	1,056	253	803	509	148	361	36,279,085	4,431,950	31,847,135
Illinois.....	1,617	487	1,130	798	240	558	37,374,571	3,992,725	33,381,846
Michigan.....	704	116	588	345	67	278	25,324,770	1,571,921	23,752,849
Wisconsin.....	977	152	825	449	92	357	31,099,345	2,945,878	28,153,467
West North Central.....	9,086	1,598	7,488	3,726	767	2,959	204,594,922	21,128,384	183,466,538
Minnesota.....	1,524	340	1,184	660	176	484	62,729,182	10,365,203	52,363,979
Iowa.....	1,762	357	1,405	699	145	554	77,559,976	2,842,177	74,717,799
Missouri.....	1,649	133	1,516	598	68	530	20,695,106	635,356	20,059,750
North Dakota.....	897	180	717	395	95	300	11,093,302	3,455,591	7,637,711
South Dakota.....	694	136	558	303	66	237	7,401,612	996,660	6,404,952
Nebraska.....	1,195	187	1,008	475	83	392	13,147,299	1,124,504	12,022,795
Kansas.....	1,365	265	1,100	596	134	462	11,968,445	1,708,893	10,259,552
South Atlantic.....	3,294	733	2,561	1,312	341	971	29,081,181	5,683,018	23,398,163
Delaware.....	46	18	28	23	12	11	832,625	212,125	620,500
Maryland.....	282	92	190	123	46	77	2,301,436	698,867	1,602,569
District Columbia.....	45	15	30	21	8	13	306,832	-----	306,832
Virginia.....	490	167	323	179	58	121	4,151,276	936,709	3,214,567
West Virginia.....	341	123	218	128	59	69	1,042,784	279,649	763,135
North Carolina.....	623	87	536	172	25	147	3,667,039	486,555	3,180,484
South Carolina.....	461	82	379	233	46	187	6,984,109	1,406,216	5,577,893
Georgia.....	739	94	645	350	62	288	8,565,082	1,312,245	7,252,837
Florida.....	267	55	212	83	25	58	1,229,998	350,652	879,346
East South Central.....	1,840	367	1,473	881	198	683	36,372,533	4,093,306	32,279,227
Kentucky.....	583	133	450	188	52	136	7,656,284	1,350,042	6,306,242
Tennessee.....	546	98	448	320	65	255	9,704,392	454,444	9,249,948
Alabama.....	356	105	251	191	61	130	5,464,610	1,464,221	4,000,389
Mississippi.....	355	31	324	182	20	162	13,547,247	824,599	12,722,648
West South Central.....	3,305	1,035	2,270	1,072	387	685	14,683,855	3,291,267	11,392,588
Arkansas.....	489	85	404	150	28	122	4,908,020	565,934	4,342,086
Louisiana.....	268	39	229	79	14	65	3,215,433	45,420	3,170,013
Oklahoma.....	966	355	611	347	144	203	2,589,652	1,255,085	1,334,567
Texas.....	1,582	556	1,026	496	201	295	3,970,750	1,424,828	2,545,922
Mountain.....	1,601	528	1,073	745	276	469	23,853,659	5,683,997	18,169,662
Montana.....	431	145	286	194	73	121	7,438,082	2,135,433	5,302,649
Idaho.....	227	86	141	106	42	64	2,358,442	808,997	1,549,445
Wyoming.....	160	47	113	72	23	49	3,219,699	452,131	2,767,568
Colorado.....	404	142	262	192	80	112	2,285,295	1,034,544	1,250,751
New Mexico.....	124	48	76	55	24	31	423,764	253,249	170,515
Arizona.....	88	21	67	55	12	43	1,831,887	465,541	1,366,346
Utah.....	133	28	105	54	15	39	4,796,596	307,113	4,489,483
Nevada.....	34	11	23	17	7	10	1,499,894	225,989	1,273,905
Pacific.....	1,407	493	914	789	301	488	78,947,150	6,221,859	72,725,291
Washington.....	401	94	307	201	54	147	4,794,773	948,989	3,845,784
Oregon.....	278	91	187	149	58	91	3,390,815	885,647	2,505,168
California.....	728	308	420	439	189	250	70,761,562	4,387,223	66,374,339

TABLE 3.—*Estimated amount of farm mortgage loans held by banks, Dec. 31, 1920, classified according to first and second mortgage, by States.*

Geographic division and State.	Total amount.	Per cent of bank loans and discounts composed of farm mortgage loans.	First mortgage.		Second mortgage.	
			Amount.	Per cent of total.	Amount.	Per cent of total.
United States.....	1,447,482,926	4.97	1,339,321,821	92.53	108,161,105	7.47
New England.....	93,685,241	3.29	93,625,172	99.94	60,069	.06
Maine.....	5,405,659	3.89	5,371,003	99.37	34,656	.63
New Hampshire.....	8,808,965	8.91	8,837,644	99.75	21,261	.24
Vermont.....	65,308,569	51.68	65,308,569	100.00	0	.00
Massachusetts.....	7,127,580	.36	7,126,104	99.98	1,476	.02
Rhode Island.....	333,305	.17	333,305	100.00	0	.00
Connecticut.....	6,647,273	1.66	6,647,247	99.95	3,326	.05
Middle Atlantic.....	34,148,394	.35	33,576,778	98.33	571,616	1.67
New York.....	24,017,367	.34	23,558,861	98.09	458,506	1.91
New Jersey.....	1,035,386	.18	1,027,163	99.26	8,223	.80
Pennsylvania.....	9,095,411	.41	8,990,814	98.85	104,597	1.15
East North Central.....	835,095,006	6.32	824,390,515	96.81	10,704,491	3.19
Ohio.....	51,924,862	3.63	51,114,834	98.44	810,028	1.56
Indiana.....	78,926,443	14.31	75,969,023	95.90	3,551,420	4.50
Illinois.....	105,960,642	4.98	103,629,508	97.80	2,331,134	2.20
Michigan.....	32,618,757	5.18	32,641,405	98.23	577,352	1.77
Wisconsin.....	65,670,302	11.71	62,235,745	94.77	3,434,557	5.23
West North Central.....	531,212,143	13.86	468,696,489	88.21	62,605,654	11.79
Minnesota.....	124,839,546	16.40	111,112,510	88.99	13,747,036	11.01
Iowa.....	213,325,000	23.78	197,368,290	92.52	15,956,710	7.48
Missouri.....	75,093,027	7.94	67,618,762	90.04	7,474,265	9.96
North Dakota.....	27,096,233	14.25	19,840,666	78.25	7,245,567	26.75
South Dakota.....	22,086,090	9.73	16,825,183	76.18	5,260,907	23.82
Nebraska.....	35,312,260	8.50	26,554,974	76.05	8,457,286	23.95
Kansas.....	33,449,987	8.43	28,991,104	86.67	4,458,883	13.33
South Atlantic.....	94,048,174	4.30	87,783,536	93.34	6,264,638	6.66
Delaware.....	2,632,290	4.67	1,515,682	74.58	516,608	25.42
Maryland.....	5,553,999	1.69	5,506,760	99.15	47,239	.85
District of Columbia.....	1,175,189	1.01	1,151,685	98.00	23,504	2.00
Virginia.....	13,505,099	3.42	13,239,049	98.03	266,050	1.97
West Virginia.....	4,349,929	1.79	4,286,420	98.54	63,509	1.46
North Carolina.....	24,631,385	7.77	24,022,775	97.45	628,610	2.55
South Carolina.....	17,194,252	7.38	15,982,057	92.95	1,212,195	7.05
Georgia.....	21,243,880	5.68	17,836,362	83.96	3,407,518	16.04
Florida.....	4,342,151	3.24	4,242,716	97.71	99,435	2.29
East South Central.....	101,079,669	10.82	93,389,620	92.39	7,689,989	7.61
Kentucky.....	25,883,448	8.76	25,207,890	97.39	675,558	2.61
Tennessee.....	19,338,567	6.59	18,383,270	95.06	955,297	4.94
Alabama.....	12,602,232	7.09	11,725,117	93.04	\$77,115	6.96
Mississippi.....	43,255,332	26.41	38,973,343	88.02	5,181,989	11.98
West South Central.....	73,251,166	4.60	62,732,975	85.64	10,518,191	14.36
Arkansas.....	22,269,021	12.27	18,888,772	85.05	3,320,249	14.95
Louisiana.....	26,753,164	8.19	24,430,152	91.46	2,283,012	8.54
Oklahoma.....	8,712,857	2.38	6,197,713	70.10	2,605,144	29.90
Texas.....	15,596,124	2.09	13,286,338	85.19	2,309,786	14.81
Mountain.....	55,985,755	7.43	47,592,153	85.08	8,343,602	14.92
Montana.....	13,244,397	12.50	14,087,252	73.05	5,197,145	26.85
Idaho.....	6,044,998	6.47	4,381,802	72.49	1,662,896	27.51
Wyoming.....	7,199,650	11.08	6,544,753	96.69	234,317	3.31
Colorado.....	6,068,599	2.87	5,661,312	93.29	407,187	6.71
New Mexico.....	1,221,505	2.66	1,170,446	95.82	51,059	4.18
Arizona.....	3,441,957	5.76	3,061,621	88.95	380,336	11.05
Utah.....	9,871,436	9.95	9,494,784	95.84	410,652	4.16
Nevada.....	2,924,203	11.77	2,924,203	100.00	0	.00
Pacific.....	129,027,438	6.94	127,624,583	98.91	1,402,855	1.09
Washington.....	9,242,492	3.34	8,833,219	95.16	449,273	4.84
Oregon.....	5,424,009	2.77	4,779,094	88.11	644,915	11.99
California.....	114,320,937	8.25	114,012,270	99.73	308,667	.27

FIRST AND SECOND MORTGAGE LOANS BY BANKS.

Table 1 indicates that the banks of the country held approximately 17 per cent of the estimated total farm mortgage loans outstanding in 1920. The figures in Table 3 show the relationship of farm mortgages to the total loans and discounts of all banks and also the relative amounts of first and second farm mortgages held by banks. In brief, the \$1,447,482,926 of estimated farm mortgage loans held by all banks represents only 4.97 per cent of their total loans and discounts. However, it should not be inferred that this percentage represents total farm loans. It is estimated that last December the banks throughout the country also held approximately \$3,870,000,000 of farmers' personal and collateral loans.³

It may be noted that the per cent of total loans and discounts composed of farm mortgages varies greatly from State to State. In New Hampshire, for instance, farm mortgage loans constitute only 8.91 per cent of total loans and discounts, whereas in Vermont this figure is 51.68 per cent. The percentage obtained for New Hampshire might reasonably be expected, but 51.68 per cent for Vermont is a somewhat surprising figure. Apparently farm mortgage loans have been far more popular as an investment with the banks of Vermont, particularly with the large savings banks, than with the banks of any of the other New England or Middle Atlantic States. In Mississippi, also, the percentage obtained is very high compared with those for neighboring States. The explanation in this case appears to be twofold. Mississippi is to a rather unusual extent a rural State, having no large city to swell the total loans and discounts. Secondly, the banks of this State, as indicated by the reports, hold mortgages on real estate for a large percentage of their short-time farm loans.

As in the case of farm mortgage loans by life insurance companies, so in the case of similar loans by banks, Iowa leads all other States. Minnesota and California come next in order. These three States together held 31.3 per cent of the farm mortgage loans outstanding with all banks in the United States.

On the basis of an earlier study made by the Department, it was estimated that in 1914 the banks of the country held \$739,500,000 of farm mortgage loans. The figure for farm mortgage loans by banks given in this table, namely, \$1,447,482,926, represents, therefore, an increase of \$708,000,000, or 96 per cent in six years.

Turning to the columns for first and second mortgage loans, respectively, it will be noted that in the West South Central and Mountain States the percentages of second-mortgage loans are relatively high. In the New England and Middle Atlantic States, on the other hand, such loans by banks are almost negligible. As

³ Department Bulletin No. 1048. "Bank Loans to Farmers on Personal and Collateral Security."

agriculture is developed, and first-mortgage farm loans are contracted more generally on the long-time amortization plan, second-mortgage loans will no doubt become more acceptable to banks as well as to other loan agencies in all sections of the country. This would seem to be a desirable tendency from the point of view of the prospective land-owning farmer. Among the possible ways of making second mortgages more acceptable may be mentioned a more scientific appraisal system, which should tend toward conservatism and soundness in land valuation.

INTEREST RATES ON FARM MORTGAGE LOANS.

The average current rates of interest reported by banks on farm mortgage loans are given in Table 4. Figures are given for averages of the low, high, and prevailing rates reported for each of the two classes of farm mortgage loans. On first-mortgage loans, it will be observed, the average prevailing rate for the United States, as obtained from the bank questionnaire, is 7.23 per cent. The lowest prevailing rates are found in the Middle Atlantic and New England States, the average for the former group of States being 5.96 and for the latter 5.98 per cent. The highest prevailing rates, on the other hand, are found in the Mountain States, where the average for the group is 9.07 per cent. By States, the lowest average prevailing rate on first-mortgage loans is 5.39 per cent, for New Hampshire, and the highest 9.52 per cent, for New Mexico. These two States also show, respectively, the lowest average low and the highest average high. With reference to the spread between the average low and the average high for any one State, it may be noticed that the average in Rhode Island is 6 per cent in each case, whereas in Wyoming the spread is from 8.16 per cent to 9.85 per cent, or 1.69 per cent.

TABLE 4.—Average rates of interest on farm mortgage loans in the United States, reported by banks, March, 1921.

Geographic division, State, and crop estimates district.	First-mortgage farm loans, average rate.				Second-mortgage farm loans, average rate.			
	Number of banks reporting.	Low (per cent).	High (per cent).	Prevail- ing (per cent).	Number of banks reporting.	Low (per cent).	High (per cent).	Prevail- ing (per cent).
United States..	8, 134	6. 73	7. 57	7. 23	3, 717	7. 70	8. 37	8. 10
New England.....	210	5. 78	6. 11	5. 98	15	6. 07	6. 60	6. 43
Maine.....	38	6. 03	6. 42	6. 32	4	6. 00	6. 50	6. 50
New Hampshire....	28	5. 11	5. 66	5. 39	1	5. 00	7. 00	5. 50
Vermont.....	33	5. 83	6. 32	6. 05	4	6. 00	6. 00	6. 00
Massachusetts.....	67	5. 84	6. 10	5. 98	3	6. 67	8. 00	7. 67
Rhode Island.....	5	6. 00	6. 00	6. 00	.....	.....	.....	.....
Connecticut.....	39	5. 87	6. 01	5. 99	3	6. 00	6. 00	6. 00

TABLE 4.—Average rates of interest on farm mortgage loans in the United States, reported by banks, March, 1921—Continued.

Geographic division, State, and crop estimates district.	First-mortgage farm loans, average rate.				Second-mortgage farm loans, average rate.			
	Number of banks reporting.	Low (per cent).	High (per cent).	Prevail- ing (per cent).	Number of banks reporting.	Low (per cent).	High (per cent).	Prevail- ing (per cent).
Middle Atlantic.....	486	5.84	5.98	5.96	123	5.98	6.00	6.00
New York.....	215	5.81	5.96	5.94	56	6.00	6.00	6.00
District 1.....	10	5.85	6.00	6.00	3	6.00	6.00	6.00
2.....	2	6.00	6.00	6.00	1	6.00	6.00	6.00
3.....	57	5.74	5.92	5.90	14	6.00	6.00	6.00
4.....	40	5.79	5.96	5.92	12	6.00	6.00	6.00
5.....	20	5.92	6.00	5.98	4	6.00	6.00	6.00
6.....	21	5.93	5.95	6.00	7	6.00	6.00	6.00
7.....	8	5.75	5.88	5.88	2	6.00	6.00	6.00
8.....	39	5.79	5.99	5.92	11	6.00	6.00	6.00
9a.....	18	5.81	6.00	5.99	2	6.00	6.00	6.00
New Jersey.....	35	5.94	6.00	6.00	11	6.00	6.00	6.00
District 1.....	3	6.00	6.00	6.00	2	6.00	6.00	6.00
2.....	2	6.00	6.00	6.00				
3.....	6	6.00	6.00	6.00	2	6.00	6.00	6.00
5.....	16	5.88	6.00	6.00	3	6.00	6.00	6.00
7.....	5	6.00	6.00	6.00	3	6.00	6.00	6.00
9.....	3	6.00	6.00	6.00	1	6.00	6.00	6.00
Pennsylvania.....	236	5.86	6.00	5.97	56	5.96	6.00	6.00
District 1.....	18	6.00	6.11	6.00	8	6.00	6.00	6.00
2.....	20	5.95	6.00	6.00	8	6.00	6.00	6.00
3.....	13	6.00	6.00	6.00	5	6.00	6.00	6.00
4.....	24	6.00	6.00	6.00	3	6.00	6.00	6.00
5.....	47	5.76	5.98	5.95	7	6.00	6.00	6.00
6.....	16	6.00	6.06	6.03	5	6.00	6.00	6.00
7.....	34	6.00	6.00	6.00	5	6.00	6.00	6.00
8.....	25	5.66	5.98	5.96	6	5.67	6.00	6.00
9.....	39	5.66	5.94	5.88	9	5.94	6.00	6.00
East North Central..	1,816	5.97	6.78	6.42	512	6.44	7.02	6.77
Ohio.....	352	6.10	6.85	6.40	55	6.64	6.98	6.84
District 1.....	66	6.05	6.64	6.35	13	6.46	6.92	6.69
2.....	38	6.09	6.42	6.38	4	6.50	7.00	7.00
3.....	57	6.22	6.92	6.62	5	7.00	7.20	7.20
4.....	37	6.05	6.54	6.34	8	6.75	7.00	6.88
5.....	50	6.02	6.70	6.30	12	6.83	7.08	7.00
6.....	30	6.17	6.43	6.35	1	6.00	6.00	6.00
7.....	30	6.03	6.37	6.27	7	6.29	6.43	6.43
8.....	19	6.18	6.89	6.61	3	6.67	8.00	7.00
9.....	25	6.20	6.72	6.40	2	7.00	7.00	7.00
Indiana.....	370	6.09	7.01	6.56	125	6.58	7.42	7.02
District 1.....	25	6.04	6.90	6.48	9	6.78	7.67	7.33
2.....	51	6.03	7.07	6.54	22	6.55	7.45	6.98
3.....	43	6.21	6.95	6.70	19	6.55	7.21	7.03
4.....	45	6.04	7.13	6.59	10	6.40	7.20	6.65
5.....	78	6.08	7.06	6.60	33	6.62	7.45	7.06
6.....	29	6.19	6.83	6.57	9	6.67	7.89	7.33
7.....	49	6.06	7.12	6.52	14	6.50	7.21	6.75
8.....	27	6.11	7.07	6.59	4	6.50	7.75	7.50
9.....	23	6.04	6.65	6.28	5	6.80	7.20	6.90
Illinois.....	462	5.84	6.57	6.32	127	6.40	6.72	6.60
District 1.....	63	5.70	6.54	6.25	13	6.15	6.38	6.35
3.....	65	5.45	6.28	6.01	13	6.00	6.42	6.19
4.....	58	5.72	6.60	6.35	22	6.52	6.89	6.75
4a.....	72	5.85	6.60	6.35	20	6.35	6.75	6.55
5.....	48	5.61	6.34	6.17	12	6.38	6.58	6.58
6.....	44	5.81	6.53	6.20	18	6.42	6.83	6.64
6a.....	51	6.12	6.84	6.58	19	6.58	6.95	6.87
7.....	43	6.26	6.70	6.47	3	6.00	6.00	6.00
9.....	18	6.89	7.11	7.00	7	7.00	7.00	7.00
Michigan.....	254	6.21	6.84	6.62	63	6.52	6.97	6.75
District 1.....	22	6.59	7.00	6.98	5	6.80	7.00	7.00
2.....	17	6.74	7.00	6.94	2	7.00	7.00	7.00
3.....	9	6.89	7.00	7.00				
4.....	8	6.25	7.00	6.75	2	6.00	7.00	6.50
5.....	27	6.31	6.96	6.81	6	7.00	7.17	6.92
6.....	31	6.26	6.97	6.80	14	6.79	7.00	6.96
7.....	38	6.08	6.72	6.49	6	6.33	7.00	6.75
8.....	48	5.96	6.62	6.34	11	6.00	6.82	6.41
9.....	54	5.99	6.80	6.43	17	6.47	6.94	6.68

TABLE 4.—Average rates of interest on farm mortgage loans in the United States, reported by banks, March, 1921—Continued.

Geographic division, State, and crop estimates district.	First-mortgage farm loans, average rate.				Second-mortgage farm loans, average rate.			
	Number of banks reporting.	Low (per cent.).	High (per cent.).	Prevail- ing (per cent.).	Number of banks reporting.	Low (per cent.).	High (per cent.).	Prevail- ing (per cent.).
East North Central— Continued.								
Wisconsin.....	378	5.73	6.70	6.31	142	6.25	6.98	6.68
District 1.....	69	5.97	7.34	6.81	42	6.87	7.83	7.43
2.....	34	6.10	7.06	6.65	15	6.53	7.37	7.10
3.....	21	6.17	7.07	6.62	4	6.25	7.25	6.75
4.....	43	6.01	6.72	6.24	13	6.00	6.77	6.46
5.....	29	5.67	6.62	6.31	6	6.17	6.67	6.46
6.....	79	5.31	6.30	5.93	28	5.71	6.39	6.14
7.....	28	5.77	6.59	6.14	6	6.17	6.67	6.25
8.....	42	5.56	6.44	6.12	15	5.87	6.33	6.20
9.....	33	5.39	6.18	6.06	13	5.85	6.15	6.08
West North Central..	2,615	6.52	7.66	7.19	1,804	7.79	8.66	8.32
Minnesota.....	520	6.13	7.38	6.86	407	7.47	8.49	8.04
District 1.....	80	6.44	7.98	7.42	84	8.21	9.40	8.98
2.....	28	7.04	8.71	8.07	18	8.33	9.61	8.97
3.....	13	6.50	8.31	7.73	3	8.33	9.33	9.33
4.....	61	6.17	7.28	6.95	58	7.53	8.49	8.14
5.....	87	5.95	7.20	6.72	68	7.14	8.08	7.64
6.....	72	6.00	7.55	6.85	38	7.59	8.62	8.07
7.....	48	6.09	6.89	6.50	47	7.29	8.18	7.91
8.....	62	5.85	6.85	6.37	48	6.99	8.01	7.46
9.....	69	5.96	6.91	6.38	43	6.63	7.36	6.95
Iowa.....	442	5.86	6.85	6.44	255	6.98	7.75	7.49
District 1.....	38	6.00	6.92	6.60	32	7.22	7.91	7.64
2.....	49	5.67	6.87	6.39	42	6.82	7.79	7.46
3.....	61	5.91	6.73	6.44	24	6.88	7.48	7.39
4.....	43	5.93	6.94	6.65	43	7.19	7.98	7.66
5.....	52	5.77	6.91	6.36	30	6.87	7.77	7.54
6.....	77	5.78	6.64	6.31	18	6.50	7.44	6.94
7.....	34	5.85	6.97	6.46	22	6.96	7.86	7.61
8.....	31	6.08	7.13	6.53	24	7.54	7.75	7.67
9.....	57	5.86	6.88	6.40	20	6.58	7.42	7.15
Missouri.....	408	6.64	7.47	7.13	195	7.39	7.83	7.66
District 1.....	53	6.41	7.33	6.92	33	7.20	7.62	7.50
2.....	38	6.45	7.37	6.95	26	7.31	7.81	7.56
3.....	41	5.98	6.98	6.45	19	6.95	7.47	7.21
4.....	57	6.30	7.46	7.06	25	7.44	7.96	7.82
5.....	64	6.77	7.62	7.31	32	7.44	7.87	7.73
6.....	53	6.17	7.01	6.65	11	6.64	7.36	7.09
7.....	35	7.10	7.77	7.54	14	7.71	8.14	7.89
8.....	38	7.75	8.05	7.92	21	8.00	8.19	8.10
9.....	29	7.50	7.97	7.84	14	7.79	8.00	7.93
North Dakota.....	335	7.26	8.86	8.35	304	9.15	9.92	9.71
District 1.....	50	7.48	9.04	8.53	51	9.75	10.00	9.94
2.....	52	7.18	8.69	8.23	47	9.17	9.91	9.78
3.....	64	6.76	8.25	7.73	57	8.46	9.77	9.34
4.....	32	8.09	9.80	9.41	26	9.88	10.00	9.92
5.....	30	7.25	8.63	8.13	23	9.13	9.91	9.67
6.....	33	6.48	8.41	7.70	32	8.66	9.87	9.50
7.....	21	8.36	9.86	9.38	15	9.73	10.00	9.87
8.....	21	7.90	9.50	9.07	19	9.58	10.00	10.00
9.....	32	6.89	8.77	8.17	34	8.78	9.94	9.69
South Dakota.....	230	6.73	8.13	7.55	190	8.32	9.47	9.02
District 1.....	16	8.78	10.12	9.75	14	9.79	10.14	9.86
2.....	39	6.73	8.17	7.57	31	8.48	9.42	8.98
3.....	48	6.39	7.82	7.25	45	8.01	9.51	8.92
4.....	16	7.81	9.44	8.75	7	8.43	10.00	9.71
5.....	23	6.72	8.30	7.63	17	8.88	9.47	9.35
6.....	47	5.90	7.27	6.68	38	7.32	9.21	8.47
7.....	5	8.50	10.00	9.20	4	9.00	10.00	9.75
8.....	11	7.45	9.23	8.27	14	9.21	10.00	9.57
9.....	25	6.32	7.12	6.88	20	8.02	8.85	8.70

TABLE 4.—Average rates of interest on farm mortgage loans in the United States, reported by banks, March, 1921—Continued.

Geographic division, State, and crop estimates district.	First-mortgage farm loans, average rate.				Second-mortgage farm loans, average rate.			
	Number of banks reporting.	Low (per cent).	High (per cent).	Prevail- ing (per cent).	Number of banks reporting.	Low (per cent).	High (per cent).	Prevail- ing (per cent).
West North Central— Continued.								
Nebraska.....	298	6.49	7.78	7.19	218	7.50	8.60	8.12
District 1.....	14	8.79	9.79	9.25	10	9.50	9.50	9.50
2.....	8	7.25	9.50	8.50	6	7.50	9.67	8.83
3.....	46	6.24	7.70	7.04	45	7.46	8.83	8.28
4.....	19	8.21	9.39	8.82	15	9.67	10.00	10.00
5.....	33	6.15	7.64	6.95	26	7.50	8.88	8.35
6.....	69	5.92	6.91	6.55	52	6.90	7.91	7.43
7.....	29	7.28	8.98	8.23	12	7.75	8.83	8.17
8.....	31	6.29	7.63	7.02	19	6.92	7.92	7.50
9.....	49	6.00	7.07	6.48	33	7.15	8.35	7.74
Kansas.....	382	6.92	7.76	7.30	235	7.67	8.39	8.06
District 1.....	22	7.02	8.64	7.95	10	7.90	9.00	8.70
2.....	46	6.34	7.48	7.04	35	7.60	8.17	7.84
3.....	61	6.13	7.26	6.79	39	7.37	8.13	7.78
4.....	11	7.27	8.27	7.91	5	8.00	8.60	8.30
5.....	51	6.74	7.54	7.27	34	7.47	8.19	7.90
6.....	50	6.50	7.46	7.06	28	7.80	8.14	7.99
7.....	22	8.05	9.36	8.61	12	8.67	9.50	9.25
8.....	56	6.61	7.79	7.33	38	7.59	8.53	8.16
9.....	63	6.80	7.86	7.35	34	7.76	8.53	8.07
South Atlantic.....	786	7.15	7.49	7.33	339	7.42	7.79	7.60
Delaware.....	12	6.00	6.00	6.00	6	6.00	6.00	6.00
Maryland.....	50	5.96	6.00	6.00	12	6.00	6.00	6.00
District 1.....	6	5.92	6.00	6.00	5	6.00	6.00	6.00
2.....	17	5.97	6.00	6.00	2	6.00	6.00	6.00
3.....	5	5.80	6.00	6.00	3	6.00	6.00	6.00
4.....	8	6.00	6.00	6.00	2	6.00	6.00	6.00
5.....	8	6.00	6.00	6.00	2	6.00	6.00	6.00
6.....	1	6.00	6.00	6.00				
7.....	5	6.00	6.00	6.00				
District of Columbia	1	6.00	7.00	6.00	1	6.00	8.00	8.00
Virginia.....	110	6.04	6.26	6.17	32	6.06	6.28	6.16
District 2.....	19	6.00	6.00	6.00	5	6.00	6.00	6.00
4.....	14	6.00	6.00	6.00	5	6.00	6.00	6.00
5.....	19	5.97	6.11	6.03	4	6.00	6.00	6.00
6.....	12	6.00	6.00	6.00	3	6.00	6.00	6.00
7.....	22	6.00	6.00	6.00	5	6.00	6.00	6.00
8.....	10	6.20	6.90	6.80	3	6.33	6.67	6.33
9.....	14	6.21	7.29	6.75	7	6.14	7.00	6.57
West Virginia.....	51	6.00	6.16	6.06	13	6.00	6.31	6.08
District 1.....	10	6.00	6.00	6.00	3	6.00	6.00	6.00
2.....	10	6.00	6.00	6.00	3	6.00	6.67	6.00
3.....	9	6.00	6.22	6.00	3	6.00	6.67	6.33
4.....	8	6.00	6.75	6.38	4	6.00	6.00	6.00
5.....	2	6.00	6.00	6.00				
6.....	9	6.00	6.00	6.00				
7.....	3	6.00	6.00	6.00				
North Carolina.....	99	6.04	6.31	6.12	42	6.05	6.36	6.19
District 1.....	12	6.00	6.42	6.25	6	6.00	6.83	6.50
2.....	13	6.00	6.00	6.00	4	6.00	6.00	6.00
3.....	17	6.00	6.24	6.18	7	6.00	6.57	6.43
4.....	9	6.22	6.22	6.22	3	6.00	6.00	6.00
5.....	23	6.00	6.17	6.00	10	6.00	6.20	6.00
6.....	11	6.00	6.18	6.00	5	6.00	6.00	6.00
7.....	3	6.67	8.00	7.00	1	8.00	8.00	8.00
8.....	7	6.00	7.14	6.14	4	6.00	6.50	6.00
9.....	4	6.00	6.00	6.00	2	6.00	6.00	6.00
South Carolina.....	176	7.76	8.01	7.98	90	7.88	8.02	7.99
District 1.....	38	7.79	8.00	7.95	20	7.95	8.00	8.00
2.....	21	7.38	8.00	7.93	13	7.46	8.00	7.92
3.....	29	7.93	8.00	8.00	13	8.00	8.00	8.00
4.....	24	7.62	8.00	8.00	13	7.85	8.00	8.00
5.....	28	7.86	8.00	7.95	14	7.93	8.00	8.00
6.....	9	7.89	8.00	7.94	3	8.00	8.00	8.00
7.....	27	7.83	8.07	8.00	14	8.00	8.14	8.00

TABLE 4.—Average rates of interest on farm mortgage loans in the United States, reported by banks, March, 1921—Continued.

Geographic division, State, and crop estimates district.	First-mortgage farm loans, average rate.				Second-mortgage farm loans, average rate.			
	Number of banks reporting.	Low (per cent.).	High (per cent.).	Prevail- ing (per cent.).	Number of banks reporting.	Low (per cent.).	High (per cent.).	Prevail- ing (per cent.).
South Atlantic—Con.								
Georgia.....	241	8.01	8.56	8.28	126	8.10	8.75	8.40
District 1.....	16	7.94	8.25	8.00	6	7.83	8.33	8.00
2.....	28	7.96	8.43	8.21	13	8.15	8.46	8.23
3.....	21	8.00	8.19	8.10	11	8.00	8.18	8.09
4.....	54	7.98	8.67	8.37	25	7.96	8.80	8.48
5.....	38	7.92	8.58	8.25	21	8.00	8.86	8.33
6.....	27	7.96	8.78	8.33	13	8.62	9.08	8.77
7.....	20	8.15	8.35	8.20	12	8.25	8.42	8.33
8.....	23	8.35	9.04	8.78	16	8.12	9.00	8.62
9.....	14	7.93	8.29	7.93	9	8.00	8.44	8.44
Florida.....	46	8.17	8.96	8.59	17	8.47	8.82	8.65
District 1.....	7	8.57	9.43	9.14	5	8.80	9.20	9.20
3.....	8	8.25	9.75	9.38	1	10.00	10.00	10.00
5.....	24	7.92	8.42	8.12	8	8.00	8.25	8.00
8.....	7	8.57	9.43	8.71	3	8.67	9.33	9.00
East South Central...	608	7.21	7.79	7.57	241	7.61	7.96	7.80
Kentucky.....	134	6.18	6.72	6.45	33	6.30	6.61	6.47
District 1.....	18	6.22	7.00	6.56	1	6.00	6.00	6.00
2.....	28	6.07	6.54	6.27	6	6.17	6.50	6.33
3.....	4	6.00	6.00	6.00	2	6.00	6.00	6.00
5.....	35	5.93	6.31	6.15	14	6.07	6.21	6.11
6.....	4	6.00	6.50	6.25	1	8.00	8.00	8.00
7.....	16	6.75	7.38	7.12	2	7.00	9.00	8.00
7a.....	14	6.43	7.14	6.86	2	6.00	7.00	7.00
8.....	14	6.14	6.79	6.46	5	6.80	6.80	6.80
9.....	1	6.00	8.00	6.00				
Tennessee.....	171	6.93	7.85	7.51	56	7.21	7.98	7.64
District 1.....	28	7.32	8.07	7.82	12	7.33	8.17	7.83
2.....	29	6.48	7.48	6.91	10	6.80	7.90	7.30
3.....	14	6.64	7.57	7.21	2	7.00	8.00	7.50
4.....	22	7.00	8.82	8.05	7	7.43	8.86	8.43
5.....	29	6.52	7.41	7.24	12	6.67	7.17	7.00
6.....	8	6.50	7.25	7.12	3	7.33	8.00	7.67
7.....	16	7.50	7.88	7.81	4	8.00	8.00	8.00
8.....	10	7.80	8.00	8.00	4	8.00	8.00	8.00
9.....	15	7.07	8.00	7.67	2	8.00	9.00	8.00
Alabama.....	149	7.95	8.40	8.18	68	8.12	8.50	8.29
District 1.....	10	7.80	8.20	8.00	5	8.40	8.40	8.40
2.....	17	8.00	8.41	8.24	8	8.00	8.00	8.00
2a.....	19	7.79	8.84	8.42	3	8.67	10.33	9.33
3.....	16	8.00	8.12	8.00	5	8.40	8.80	8.40
4.....	12	8.00	8.00	8.00	9	8.00	8.00	8.00
5.....	12	7.92	8.17	8.17	7	8.00	8.29	8.29
6.....	20	7.95	9.00	8.45	9	8.22	9.33	8.89
7.....	5	8.00	8.00	8.00	1	8.00	8.00	8.00
8.....	15	8.00	8.73	8.27	8	8.00	8.88	8.25
9.....	23	8.00	8.00	8.00	13	8.00	8.00	8.00
Mississippi.....	154	7.70	8.06	7.99	84	7.96	8.05	8.04
District 1.....	18	8.00	8.11	8.06	16	8.00	8.12	8.06
2.....	26	7.46	8.15	7.92	9	7.78	8.00	8.00
3.....	10	8.00	8.00	8.00	3	8.00	8.00	8.00
4.....	12	7.67	8.00	8.00	12	7.83	8.00	8.00
5.....	20	7.90	8.00	8.00	9	7.78	8.00	8.00
6.....	16	7.75	8.00	8.00	10	8.00	8.00	8.00
7.....	21	7.52	8.10	8.10	10	8.20	8.20	8.20
8.....	15	8.00	8.00	8.00	9	8.00	8.00	8.00
9.....	16	7.25	8.06	7.88	6	7.83	8.00	8.00
West South Central...	581	8.46	9.37	9.02	283	9.08	9.72	9.44
Arkansas.....	125	8.63	9.70	9.34	39	9.23	9.85	9.59
District 1.....	21	8.14	9.10	8.60	3	9.33	10.00	9.33
2.....	17	8.76	9.65	9.38	5	9.20	10.00	9.80
3.....	17	8.71	9.88	9.56	6	9.00	9.33	9.17
4.....	19	8.74	9.89	9.47	4	9.50	10.00	9.50
5.....	6	8.67	10.00	9.67	2	10.00	10.00	10.00
6.....	15	8.13	9.60	9.00	6	8.67	9.67	9.17
7.....	14	9.21	9.86	9.82	6	9.67	10.00	10.00
8.....	9	9.33	10.00	9.89	2	10.00	10.00	10.00
9.....	7	8.29	10.00	9.43	5	8.80	10.00	9.80

TABLE 4.—Average rates of interest on farm mortgage loans in the United States, reported by banks, March, 1921—Continued.

Geographic division, State, and crop estimates district.	First-mortgage farm loans, average rate.				Second-mortgage farm loans, average rate.			
	Number of banks reporting.	Low (per cent).	High (per cent).	Prevail- ing (per cent).	Number of banks reporting.	Low (per cent).	High (per cent).	Prevail- ing (per cent).
West South Central— Continued.								
Louisiana.....	48	7.73	8.63	8.24	19	7.95	8.95	8.50
District 1.....	5	7.80	8.40	7.90	3	7.67	8.00	7.83
2.....	6	8.00	9.00	8.54	3	8.00	9.33	8.67
3.....	7	7.57	8.86	8.43	2	8.00	10.00	9.50
4.....	3	8.00	8.00	8.00	1	8.00	8.00	8.00
5.....	10	7.90	8.40	8.20	4	8.00	8.50	8.25
6.....	3	8.00	8.67	8.00				
7.....	5	7.00	9.20	8.40	3	8.00	9.33	8.67
8.....	6	8.00	8.67	8.33	2	8.00	10.00	9.00
9.....	3	7.00	8.00	8.00	1	8.00	8.00	8.00
Oklahoma.....	185	8.39	9.37	8.98	136	9.22	9.83	9.60
District 1.....	23	8.52	9.13	8.85	16	9.19	9.69	9.44
2.....	22	7.07	8.34	7.91	20	8.60	9.68	9.28
3.....	14	8.21	9.57	9.14	13	9.08	9.69	9.62
4.....	11	8.82	9.36	9.05	8	9.38	10.00	9.50
5.....	36	8.05	9.31	8.76	22	9.23	9.82	9.55
6.....	22	8.73	9.82	9.41	12	9.33	9.83	9.67
7.....	24	8.40	9.44	8.83	21	9.29	10.00	9.76
8.....	27	9.19	9.85	9.72	22	9.64	9.91	9.86
9.....	6	9.67	10.00	10.00	2	10.00	10.00	10.00
Texas.....	223	8.58	9.35	9.05	89	9.04	9.67	9.36
District 1.....	31	9.31	9.90	9.58	19	9.47	9.89	9.63
2.....	39	8.31	9.00	8.72	15	8.53	9.53	8.97
3.....	30	8.97	9.67	9.40	9	9.11	9.78	9.56
4.....	9	9.33	10.00	9.56	3	10.00	10.00	10.00
4a.....	22	8.64	9.55	9.27	10	9.60	9.80	9.70
5.....	47	8.11	9.02	8.64	22	8.75	9.55	9.10
6.....	15	9.07	10.00	9.60	2	9.00	10.00	9.50
8.....	19	8.21	9.05	9.00	7	8.57	9.43	9.29
9.....	11	7.73	8.18	7.91	2	9.00	9.00	9.00
Mountain.....	519	8.26	9.53	9.07	278	9.19	9.82	9.57
Montana.....	169	8.64	9.81	9.50	127	9.61	9.90	9.82
District 1.....	6	8.67	9.17	9.17	4	9.50	9.75	9.75
2.....	30	9.30	10.00	9.87	28	9.93	10.00	10.00
3.....	22	8.32	9.86	9.70	20	10.00	10.20	10.00
4.....	14	7.82	9.79	9.18	7	9.14	9.71	9.43
5.....	34	8.37	9.84	9.38	25	9.68	10.00	9.88
6.....	14	8.64	9.64	9.50	12	9.00	9.42	9.33
7.....	7	7.71	10.00	8.86	4	10.00	10.00	10.00
8.....	26	8.50	9.65	9.29	17	9.00	9.71	9.62
9.....	16	9.75	9.88	9.81	10	9.70	10.00	9.90
Idaho.....	71	7.94	9.32	8.83	48	9.04	9.81	9.58
District 1.....	20	7.45	8.80	8.05	10	8.30	9.60	9.10
2.....	5	8.40	9.40	8.90				
4.....	2	10.00	10.00	10.00	2	10.00	10.00	10.00
5.....	5	6.60	9.20	8.90	6	9.00	9.67	9.67
6.....	10	8.30	10.00	9.30	9	9.78	10.00	10.00
7.....	17	7.82	9.18	8.65	8	8.38	9.75	9.12
8.....	5	9.60	10.00	10.00	6	10.00	10.00	10.00
9.....	7	8.00	9.57	9.57	7	8.86	9.86	9.71
Wyoming.....	55	8.16	9.85	9.21	26	9.04	10.15	9.58
District 1.....	9	8.33	10.00	9.44	4	8.50	10.00	9.50
2.....	8	8.75	10.50	9.38	2	9.00	11.00	9.50
3.....	5	10.00	10.80	10.40	4	10.50	10.50	10.50
4.....	3	8.33	9.67	9.67	1	8.00	12.00	10.00
5.....	8	7.88	9.25	8.75	3	8.00	10.00	9.33
6.....	6	8.67	10.00	9.50	4	9.50	10.00	9.75
7.....	2	8.00	9.50	8.00	1	8.00	9.00	8.00
8.....	5	8.00	9.20	8.30	1	9.00	9.00	9.00
9.....	9	8.56	9.56	9.00	6	9.00	10.00	9.33
Colorado.....	121	7.84	9.06	8.58	39	8.56	9.36	9.03
District 1.....	3	9.33	10.00	9.67				
2.....	32	7.25	8.45	8.09	13	7.69	8.54	8.23
3.....	11	8.00	9.36	9.09	8	9.00	9.75	9.62
4.....	16	8.00	9.12	8.44	2	8.00	8.00	8.00
5.....	4	6.88	7.38	7.38				
6.....	23	7.96	9.26	8.83	5	9.20	9.60	9.20
7.....	3	7.67	8.67	8.67	1	8.00	10.00	8.00
8.....	9	7.67	9.56	8.78	4	8.50	10.50	9.50
9.....	20	8.50	9.60	8.90	6	9.67	10.00	10.00

TABLE 4.—Average rates of interest on farm mortgage loans in the United States, reported by banks, March, 1921—Continued.

Geographic division, State and crop estimates district.	First-mortgage farm loans, average rate.				Second-mortgage farm loans, average rate.			
	Number of banks reporting.	Low (per cent.).	High (per cent.).	Prevail- ing (per cent.).	Number of banks reporting.	Low (per cent.).	High (per cent.).	Prevail- ing (per cent.).
Mountain—Contd.								
New Mexico.....	33	9.03	9.88	9.52	7	9.71	10.00	10.00
District 1.....	2	9.00	10.00	9.00	1	10.00	10.00	10.00
2.....	4	8.00	9.50	9.50	1	8.00	10.00	10.00
3.....	2	10.00	10.00	10.00				
4.....	1	8.00	10.00	8.00				
5.....	3	8.00	8.67	8.67				
6.....	13	9.38	10.00	9.62	4	10.00	10.00	10.00
7.....	2	10.00	11.00	11.00	1	10.00	10.00	10.00
8.....	5	8.80	10.00	9.40				
9.....	1	10.00	10.00	10.00				
Arizona.....	21	8.43	9.62	9.00	14	9.00	10.00	9.43
District 1.....	2	10.00	10.00	10.00	1	10.00	10.00	10.00
2.....	1	10.00	10.00	10.00	1	10.00	10.00	10.00
3.....	10	8.00	9.20	8.40	9	8.67	10.00	9.11
5.....	3	9.33	10.00	10.00				
6.....	2	7.50	10.00	8.50	2	9.00	10.00	10.00
7.....								
8.....	3	8.00	10.00	9.33	1	10.00	10.00	10.00
9.....								
Utah.....	41	7.95	9.46	8.71	15	8.20	9.73	8.90
District 1.....	3	7.67	9.67	8.33	2	8.00	9.50	8.50
2.....	16	7.62	9.19	8.44	7	8.14	9.29	8.50
3.....	3	8.67	9.33	9.33				
4.....	3	7.33	10.67	8.33	2	8.00	11.00	9.50
5.....	8	7.75	9.12	8.50	3	8.00	10.00	9.33
6.....	2	8.50	10.00	9.50				
7.....	4	9.25	9.75	9.25	1	10.00	10.00	10.00
8.....	2	8.50	10.00	10.00				
9.....								
Nevada.....	8	7.88	8.75	8.62	2	8.00	9.00	8.50
District 1.....	1	7.00	8.00	8.00				
2.....	2	8.00	9.00	8.50	1	8.00	10.00	9.00
3.....	1	8.00	8.00	8.00				
4.....	2	8.00	8.00	8.00	1	8.00	8.00	8.00
5.....								
6.....	1	8.00	8.00	8.00				
7.....								
8.....	1	8.00	12.00	12.00				
9.....								
Pacific.....	513	7.04	7.89	7.55	122	7.98	8.48	8.24
Washington.....	124	7.27	8.34	7.95	44	8.30	8.77	8.49
District 1.....	16	6.69	7.75	7.41	3	8.00	8.00	8.00
2.....	14	8.46	9.71	9.21	3	9.00	9.67	9.67
3.....	6	7.92	9.67	8.33	1	10.00	10.00	10.00
4.....	14	7.29	7.79	7.64	1	8.00	8.00	8.00
5.....	12	7.29	8.17	7.79	8	8.00	8.25	8.12
5a.....	15	7.67	8.87	8.43	11	9.00	9.45	9.14
6.....	22	6.50	7.91	7.42	9	7.67	8.44	7.89
7.....	14	7.21	8.07	8.00	4	7.75	8.50	8.25
8.....	4	7.50	9.00	8.50	2	9.00	10.00	9.00
9.....	7	7.14	7.57	7.36	2	7.50	7.50	7.50
Oregon.....	112	7.41	8.27	7.96	49	8.06	8.43	8.26
District 1.....	37	7.08	7.97	7.73	16	7.88	8.25	8.19
2.....	13	7.69	8.15	7.85	8	7.75	8.00	7.88
3.....	7	7.71	8.57	8.29	3	8.67	8.67	8.67
4.....	17	7.00	8.18	7.65	8	7.88	8.12	8.00
5.....	4	8.50	9.00	8.50	1	8.00	10.00	8.00
6.....	6	7.83	8.00	8.00	2	8.00	8.00	8.00
7.....	14	7.50	8.14	7.96	3	8.67	8.67	8.67
8.....	8	7.62	8.50	8.00	4	7.50	8.50	8.00
9.....	6	8.00	10.00	9.67	4	9.50	10.00	9.75
California.....	277	6.79	7.54	7.20	29	7.34	8.14	7.83
District 1.....	14	6.50	7.29	6.93				
2.....	5	6.60	8.00	7.60	1	8.00	8.00	8.00
3.....	4	7.00	7.75	7.25				
4.....	45	6.48	7.26	6.93	1	6.00	8.00	7.00
5.....	48	6.62	7.35	6.95	2	7.50	7.50	7.50
5a.....	51	6.98	7.51	7.34	10	7.30	7.90	7.85
6.....	7	6.71	7.57	7.14				
6a.....	2	7.50	9.00	8.00	1	8.00	10.00	8.00
8.....	101	6.95	7.74	7.38	14	7.36	8.29	7.89

On second-mortgage loans the Middle Atlantic and New England divisions have the lowest prevailing rate, while the Mountain division has the highest. Considered by States, the lowest prevailing rate, as before, is for New Hampshire, namely, 5.5 per cent, and the highest for New Mexico, 10 per cent. In several Middle Atlantic and New England States the average low and average high rates will be found to be the same, whereas for the West North Central States, which together furnished one-half of the reports on second-mortgage rates, an average spread of 0.87 per cent is shown.

Comparing the prevailing rates on first and second mortgage loans, it appears that second mortgages bear a rate of interest eighty-seven one-hundredths of 1 per cent higher than those borne on first mortgages for the United States as a whole. In three States, namely, Vermont, Virginia, and Nevada, the reports show an average rate 0.05 per cent, 0.01 per cent, and 0.12 per cent higher, respectively, on first-mortgage than on second-mortgage loans. The reasons for this irregularity in Vermont seem to be the small number of reports received on second-mortgage rates as compared with those on first-mortgage rates, and the fact as pointed out previously that the banks of Vermont hold a large amount of first mortgages in the West where the rates of interest are higher. The second-mortgage loans are presumably more generally on local farms; hence the rates charged are more nearly the local rate. For Virginia and Nevada the explanation seems to be that a relatively small number of banks reported rates on second-mortgage loans, and that the rates reported were not from the banks reporting the highest rates on first-mortgage loans. The same explanation will hold true for the various subdivisions of States or districts where the average rates reported for first mortgages exceed those for second mortgages.

A comparison of the interest rates shown in Table 4 with the rates determined by a study made by the department in 1915 indicates that although the current rates on farm mortgage loans are uniformly higher than those for the earlier date, owing, no doubt, to the increased demand for capital occasioned by war expenditures, there is a slight tendency toward equalization in rates as between different sections of the country. In other words, although the rates for all sections have increased, this increase is less marked in the States whose rates in 1915 were disproportionately high. It seems probable that the loan operations of the Federal land banks, with their uniform rates for all parts of the country, have been a leading factor in this tendency toward equalization.

The districts referred to in the table are those established by the Department in connection with the gathering of data on crop conditions. These district are indicated by number on the map, figure 1.

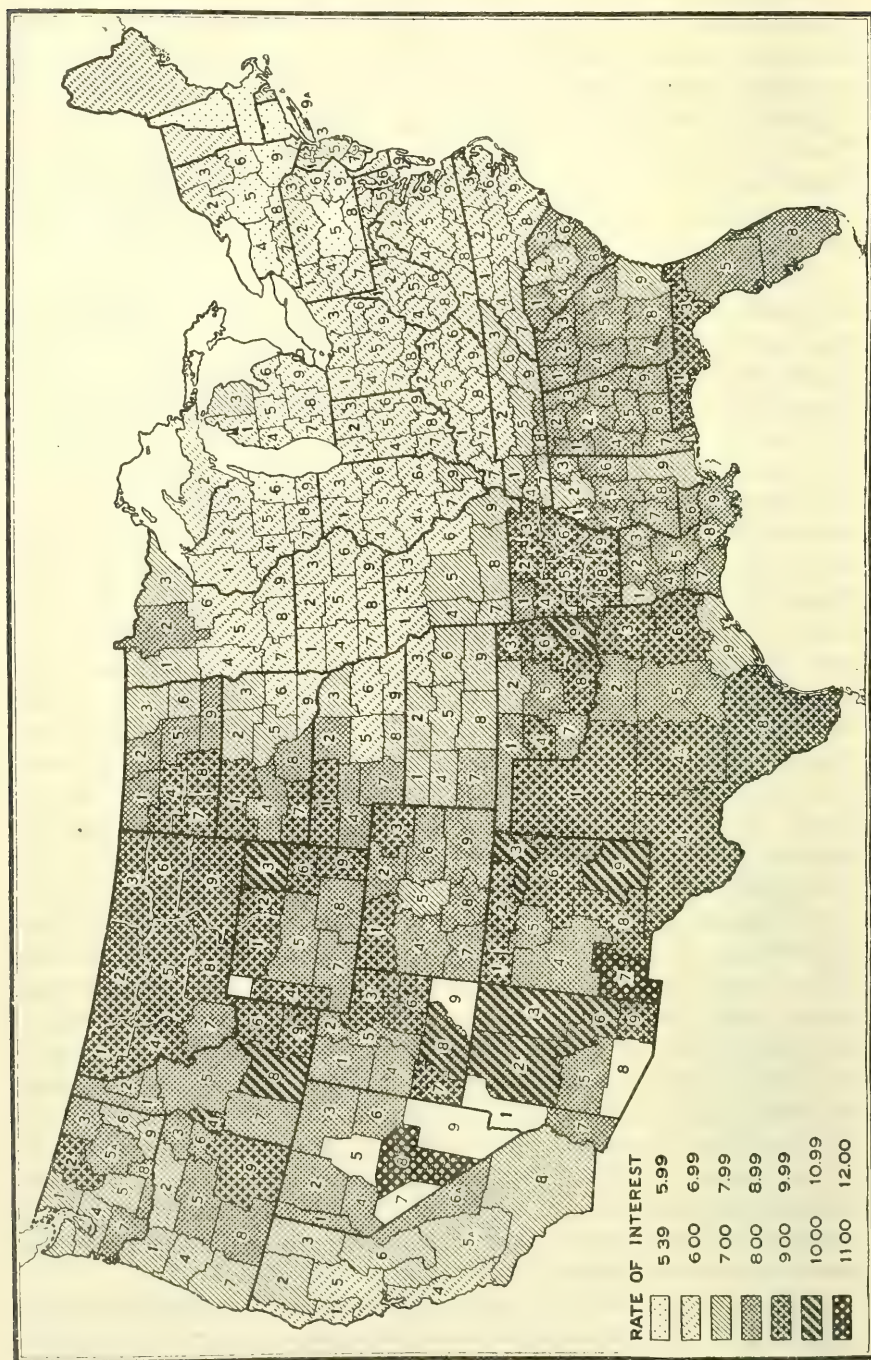


FIG. 1.—Crop estimates districts referred to in Table 4, and approximate prevailing interest rate on first mortgage farm loans in such districts.

The rates by districts, as shown on the table, are of particular significance for the tier of States comprising the Dakotas, Nebraska, Kansas, Oklahoma, and Texas. In each of these States the variation between rates in the eastern districts and the western districts is very marked. The chief explanation of this variation is the increasing meagerness and uncertainty of the rainfall as one proceeds westward in these States. The map, besides indicating by number the various districts referred to in the table, also indicates by the shading of each district the approximate prevailing rate on first-mortgage loans.

An effort was also made to obtain data on the interest charges by insurance companies. The figures obtained give an average rate for the United States of 5.82 per cent. The lowest average rate for any geographic division was 5.5 per cent, for the New England States, and the lowest for individual States was 5 per cent, for Vermont and Massachusetts. The highest average rates for any geographic division and State were 7.24 per cent, for the Mountain division, and 8.15 per cent for Utah. These figures, however, are not comparable with the rates reported by banks, since the reports indicate that the figures given were in most instances the return realized on outstanding mortgages rather than the current rates. Some of these mortgages have been held for as many as 5 or 10 years. The mortgages held by insurance companies also represent to a much greater extent selected mortgages than is the case with those held by banks. In any comparison of the rates given in Table 4 with those recently published by the Bureau of the Census, it should again be remembered that the latter are not current rates, but the rates actually being paid by farmers on their outstanding mortgages, many of which represent loans negotiated several years earlier than the census date.

An effort was made to obtain also figures on commission and other charges on mortgage loans. The information obtained on this point, however, was insufficient to warrant detailed presentation at this time. Such data as were obtained indicate that when commissions or other charges are made they amount to from one-half of 1 per cent to 3 per cent of the amount of the loan, or, on an annual basis, from two-tenths of 1 per cent to 1 per cent per year.

Table 5 gives a percentage distribution of the replies received from banks according to the prevailing rate reported on first-mortgage farm loans. In the New England, Middle Atlantic, and East North Central States most of the loans are made at 7 per cent or less, whereas in the West South Central and Mountain States a majority of the banks charge more than 9 per cent.

TABLE 5.—*Prevailing rates of interest on first-mortgage farm loans: Per cent of banks reporting the various rates, March, 1921, by States.^a*

Geographic division and State.	5 per cent.	6 per cent.	7 per cent.	8 per cent.	9 per cent.	10 per cent.	11 per cent.	12 per cent. and over.
United States...	0.7	33.6	25.8	26.7	3.5	9.6	0.0	0.1
New England.....	9.0	80.6	9.0	1.4				
Maine.....		71.1	23.6	5.3				
New Hampshire.....	57.1	42.9						
Vermont.....	3.0	87.9	9.1					
Massachusetts.....	3.0	86.6	9.0	1.4				
Rhode Island.....		100.0						
Connecticut.....		97.4	2.6					
Middle Atlantic.....	2.7	97.1	.2					
New York.....	2.8	97.2						
New Jersey.....		100.0						
Pennsylvania.....	3.0	96.6	.4					
East North Central.....	1.1	52.8	43.6	2.5				
Ohio.....		59.1	39.2	1.7				
Indiana.....		45.7	47.3	7.0				
Illinois.....	1.5	56.9	41.6					
Michigan.....		33.5	66.5					
Wisconsin.....	3.4	61.9	31.0	3.7				
West North Central.....	.1	25.8	36.2	27.0	4.7	6.2		
Minnesota.....		29.8	46.2	21.3	1.5	1.2		
Iowa.....	.7	48.6	42.1	8.6				
Missouri.....		23.5	36.8	39.7				
North Dakota.....		1.8	14.3	40.3	24.2	19.4		
South Dakota.....		20.5	33.9	21.3	5.2	19.1		
Nebraska.....		30.9	34.9	18.1	4.4	11.7		
Kansas.....		16.5	37.2	40.8	2.0	2.9		
South Atlantic.....		38.0	2.4	51.9	3.2	4.1		.4
Delaware.....		100.0						
Maryland.....		100.0						
District of Columbia.....		100.0						
Virginia.....		88.2	5.4	6.4				
West Virginia.....		94.1	5.9					
North Carolina.....		92.0	4.0	4.0				
South Carolina.....		1.1	1.1	98.3		.6		
Georgia.....			1.7	80.9	7.5	8.7		1.2
Florida.....				63.1	15.2	21.7		
East South Central.....		22.2	6.9	66.5	1.5	2.6		.3
Kentucky.....		68.7	17.2	13.4	.7			
Tennessee.....		25.1	8.2	61.4	.6	4.7		
Alabama.....				90.6	3.4	4.7		1.3
Mississippi.....			3.2	94.8	1.3	.7		
West South Central.....	.2	1.5	2.9	34.9	10.2	50.3		
Arkansas.....				25.6	12.8	61.6		
Louisiana.....				83.4	8.3	8.3		
Oklahoma.....	.5	4.3	7.0	22.7	11.4	54.1		
Texas.....		.4	1.8	39.9	8.1	49.8		
Mountain.....		.6	3.3	34.5	11.9	48.9	.2	.6
Montana.....		.6	1.8	13.6	13.6	70.4		
Idaho.....			5.6	45.1	7.0	42.3		
Wyoming.....				32.7	18.2	45.5	1.8	1.8
Colorado.....		1.7	7.4	50.4	10.7	29.8		
New Mexico.....			3.0	21.2	3.0	69.8		3.0
Arizona.....				47.6	4.8	47.6		
Utah.....				53.7	19.5	26.8		
Nevada.....				75.0	12.5			12.5
Pacific.....		2.7	47.0	44.0	1.8	4.5		
Washington.....			27.4	57.3	4.0	11.3		
Oregon.....		3.6	13.4	72.3	3.6	7.1		
California.....		3.6	69.3	26.7		.4		

^a Rates involving fractions of 1 per cent are approximated to the nearest unit.

TERM OF LOAN AND METHOD OF REPAYMENT.

Farm mortgage loans by banks are usually made for relatively short periods of time. Only rarely do such loans run for a period as long as 5 years. Insurance companies make loans as a rule for somewhat longer periods of time. Of 182 insurance companies which gave information on this question, 102 stated that the terms of their loans were not over 5 years; 72 that they loaned for not over 10 years; and 6 that they had some loans of more than 10 years maturity. Of 65 mortgage bankers who reported on this question, 34 stated that the terms of their loans were not over 5 years; 27 that they were not over 10 years; and 4 that some loans were for more than 10 years.

On the question of the method of repayment of loans, 177 insurance companies and 61 mortgage bankers reported as follows: Thirty-three insurance companies and 8 mortgage bankers stated that their loans were straight loans to be paid at maturity; 17 insurance companies and 5 mortgage bankers that repayment was optional at any time; 18 insurance companies and 9 mortgage bankers that repayment could be made in whole or in part after specified periods of from 1 to 5 years. Eighty-four insurance companies and 34 mortgage bankers stated that payments could be made on the principal on any interest date, in multiples of from \$100 to \$500, or one-fifth or one-tenth of the principal in any one year, after the lapse of a certain period varying from 1 to 5 years. Nineteen insurance companies and 1 mortgage banker stated that certain annual payments were required, sometimes specified as \$100 to \$500, or one-fifth or one-tenth of the loan, while 6 insurance companies and 4 mortgage bankers reported using the amortization plan of loans running for 20 to 30 years.

CONCLUSION.

While the increase in farm mortgage indebtedness during the last decade, as indicated on the earlier pages of this bulletin, appears almost startling, such increase is not in itself a cause for alarm. It is rather a logical result of increased market value of farms. The increase in these values, in turn, reflects better farm incomes during the decade in question than prevailed during preceding decades, these incomes being to a considerable extent invested in added permanent improvements in the form of buildings, fences, silos, and drainage and irrigation systems.

A very considerable percentage of farm mortgages are the result of land transfers, the mortgage, like tenancy, forming a rung in the agricultural ladder leading to farm ownership. The size of the mortgage naturally tends to bear a direct relationship to the purchase price of the farm.

To the extent that farm mortgages are the result of investments in productive permanent improvements and equipment by existing farm owners, they evidence progress and not regression. In general, the increase in farm mortgages during each decade since data on this subject were first gathered by the census has been most marked in sections which have made the greatest progress during the decade. Even where improvements of the kind above mentioned are paid for out of savings instead of with the proceeds of loans, the increased value and price of a farm is quite certain to result in a larger mortgage in case the farm is transferred to a new owner.

In spite of the great increase in farm mortgage debt during the past decade, an increase which for the country as a whole has slightly more than kept pace with the increase in land values, it may be doubted if any other industry shows so small a percentage of mortgage or bonded debt as agriculture. The farm mortgage debt in 1910, so far as this debt was ascertained by the census, represented 27.3 per cent of the value of the mortgaged farms, while that in 1920 represented 29.1 per cent of the value of the farms for which mortgage debt was reported. The total farm mortgage debt, indicated by the estimated figures in Table 1, constitutes 12.9 per cent of the total farm values in the United States.

While the farm mortgage debt considered as a whole is thus but a relatively small percentage of the total farm values, and only about 2 per cent more of the value of the mortgaged farms than was the case in 1910, it is true beyond doubt that many individual farmers who purchased land during the recent boom period assumed mortgages which even with a continuation of fair prices for agricultural products would have been heavy burdens, and which, with the present marked disparity between prices of farm products and prices of supplies and equipment which the farmer must buy, are a matter of very serious concern.

As sources of farm mortgage loans the commercial banks with upward of a billion and a half of such loans continue to be of first importance. Ranking second as a source of farm mortgage loans are the life insurance companies, with total outstanding loans of a billion and a quarter.

The reports of loans reported by farm mortgage bankers, as explained on an earlier page, are very incomplete. Institutions of this class therefore are a more important source of farm mortgage loans than the figures in Table 1 indicate. Not only do these organizations as a class hold a considerably larger amount than the quarter of a billion dollars reported, but they annually place a large volume of farm mortgages which are passed on to other investors. This, of course, is true also of commercial banks, particularly those operating in rural districts.

State funds or loan agencies constitute a source of importance only in a few States, the State of South Dakota being particularly noteworthy in this respect.

While the banks operating under the Federal Farm Loan System as yet hold but a small percentage of the total farm mortgage loans they are a potential source of far-reaching significance. In spite of the brief period of their existence and the handicap under which they have hitherto operated, these banks now hold more than one-tenth of all the mortgages in 14 States. In Florida, Mississippi, and Utah they hold one-sixth, and in West Virginia more than one-fifth. These banks are no doubt a leading factor in bringing about a closer approach to uniformity in interest rates for various sections of the country and in keeping such rates more nearly on a par with charges for loans on urban real estate. While the maximum loan that may be made by the Federal land banks to any one individual is at present too low fully to meet the legitimate demands of borrowers in certain of the more highly developed sections of the country, the type of loan offered by these banks is particularly well adapted to the purchase of land by prospective farmers, as well as to the funding of existing mortgage indebtedness. The long term of these loans and the amortization plan of repayment further tend to make it easier to obtain an additional loan on second mortgage than is the case where the first mortgage runs for a short period and is not diminished from year to year by an amortization payment. This is also an advantage to the landless farmer, since it makes it more possible for him to become an owner even when his available cash resources are relatively small.

It seems probable that other loan institutions will be influenced by the example of the Federal land banks to make the terms and methods involved in their loans more generally adapted to the farmers' needs; hence that the time of enforced short-term mortgages, heavy commission charges, and the necessity of frequent renewals, coupled in times of depression with danger of foreclosures, is about to give way to a farm-credit situation more favorable to agricultural stability and prosperity.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY

▽





UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 1048

Contribution from the Office of Farm Management
and Farm Economics

G. W. FORSTER, Acting Chief



Washington, D. C.

February 7, 1922

BANK LOANS TO FARMERS ON PERSONAL AND COLLATERAL SECURITY.

By V. N. VALGREN, *Associate Agricultural Economist*, and ELMER E. ENGELBERT,
Junior Economist in Farm Finance.

CONTENTS.

	Page.		Page.
Amount of personal and collateral bank loans to farmers.....	2	Minimum balance requirements against bank loans to farmers on personal and collateral security.....	17
The estimated amount of personal and col- lateral loans to farmers.....	3	Interest collections in advance.....	20
Seasonal fluctuation in personal and collateral loans to farmers.....	4	Nature of security for farmers' personal and collateral loans.....	20
Rates of interest.....	6	Term of loan.....	22
		Conclusion.....	25

A very large part of the world's business is conducted on a credit basis. In proportion to the magnitude of the industry, it is perhaps safe to say that a smaller amount of credit is used by farmers than by any other important class. The outstanding loans to farmers in the United States, nevertheless, amount to a significant part of the credit of the country. The present farm mortgage credit from such data as are available has been estimated at a sum exceeding 8 billions of dollars. The information available on personal and collateral credit to farmers is even less satisfactory than that concerning farm mortgage credit. No attempt will be made at this time to present an estimate of the total amount of such credit.

By far the most important single source of personal and collateral credit to farmers, as well as to most other industries, is found in the commercial banks of the country. With a view to obtaining more comprehensive information concerning this source of rural credit, the Department of Agriculture recently sent to all banks in the United States a questionnaire on loans to farmers. The results of this inquiry, so far as it relates to short-time or personal and collateral credit, is summarized on the succeeding pages.

AMOUNT OF PERSONAL AND COLLATERAL BANK LOANS TO FARMERS.

The reported amount of bank loans to farmers on personal and collateral security, as well as the estimated total amount of such loans outstanding for all banks on December 31, 1920, will be found in Table 1. Figures are given for States and geographic divisions, as well as for the United States as a whole. The table also shows the extent to which the banks of the country replied to the questionnaire, and the percentage that the estimated short-time loans to farmers constitute of the total loans and discounts of the banks as given in the latest available report of the Comptroller of the Currency.

TABLE 1.—*Personal and collateral bank loans to farmers outstanding Dec. 31, 1920, by States.*

Geographic division and State.	Total number of banks (Comptroller's report).	Number of banks reporting.	Number reporting farm loans.	Amount reported.	Estimated amount for all banks.	Per cent of banks' total loans and discounts.
United States.....	30, 178	13, 540	10, 261	\$1, 586, 536, 310	\$3, 869, 891, 415	13. 29
New England.....	1, 129	661	296	11, 893, 052	26, 941, 166	. 92
Maine.....	161	82	50	2, 862, 905	6, 515, 518	4. 69
New Hampshire.....	126	51	36	956, 827	1, 949, 027	1. 96
Vermont.....	108	41	34	3, 944, 688	12, 493, 623	9. 89
Massachusetts.....	466	335	109	2, 526, 033	3, 270, 017	. 17
Rhode Island.....	48	33	8	91, 471	188, 086	. 10
Connecticut.....	220	119	59	1, 511, 128	2, 524, 892	. 63
Middle Atlantic.....	3, 009	1, 709	787	71, 724, 400	106, 806, 377	1. 10
New York.....	1, 063	620	319	36, 603, 418	52, 002, 471	. 75
New Jersey.....	393	251	76	6, 463, 992	16, 369, 101	2. 87
Pennsylvania.....	1, 553	838	392	28, 656, 990	38, 434, 805	1. 75
East North Central.....	5, 507	2, 645	2, 103	300, 259, 595	656, 326, 611	12. 38
Ohio.....	1, 153	544	414	48, 993, 665	106, 983, 846	7. 48
Indiana.....	1, 056	509	434	64, 402, 727	127, 910, 904	23. 19
Illinois.....	1, 617	798	592	97, 904, 600	253, 967, 783	11. 93
Michigan.....	704	345	266	37, 355, 710	50, 630, 088	8. 03
Wisconsin.....	977	449	397	51, 602, 893	116, 833, 990	20. 83
West North Central.....	9, 085	3, 726	3, 236	594, 737, 791	1, 562, 987, 613	40. 77
Minnesota.....	1, 524	660	564	100, 155, 871	235, 078, 342	30. 87
Iowa.....	1, 762	699	591	152, 301, 415	400, 816, 955	44. 68
Missouri.....	1, 649	598	493	65, 199, 671	211, 053, 938	22. 32
North Dakota.....	897	395	361	49, 879, 816	118, 920, 813	62. 58
South Dakota.....	694	303	261	55, 881, 624	154, 311, 092	67. 98
Nebraska.....	1, 195	475	423	81, 778, 750	204, 389, 176	49. 21
Kansas.....	1, 365	596	543	89, 540, 644	238, 411, 297	60. 07
South Atlantic.....	3, 294	1, 312	953	117, 186, 072	313, 184, 956	14. 34
Delaware.....	46	23	18	1, 773, 485	3, 438, 537	7. 89
Maryland.....	282	123	71	9, 494, 333	17, 913, 727	5. 45
District of Columbia.....	45	21	2	57, 000	537, 820	. 46
Virginia.....	490	179	128	18, 115, 857	52, 701, 208	13. 36
West Virginia.....	341	128	70	5, 127, 875	15, 663, 408	6. 44
North Carolina.....	623	172	124	10, 528, 270	61, 026, 032	19. 24
South Carolina.....	461	233	192	29, 099, 462	67, 413, 772	28. 93
Georgia.....	739	350	291	38, 701, 550	83, 986, 661	22. 45
Florida.....	267	83	57	4, 288, 240	10, 503, 791	7. 83
East South Central.....	1, 840	881	714	74, 646, 549	185, 981, 673	19. 93
Kentucky.....	583	188	148	20, 855, 446	61, 201, 963	20. 70
Tennessee.....	546	320	251	20, 823, 722	45, 725, 307	15. 57
Alabama.....	356	191	163	18, 859, 715	40, 424, 370	22. 46
Mississippi.....	355	182	152	14, 107, 666	38, 630, 033	23. 58

TABLE 1.—*Personal and collateral bank loans to farmers outstanding Dec. 31, 1920, by States—Continued.*

Geographic division and State.	Total number of banks (Comptroller's report).	Number of banks reporting.	Number reporting farm loans.	Amount reported.	Estimated amount for all banks.	Per cent of banks' total loans and discounts.
West South Central	3,305	1,072	946	\$144,749,773	\$541,988,607	34.07
Arkansas	489	150	143	17,083,156	72,134,936	39.84
Louisiana	268	79	61	12,340,116	69,753,012	21.37
Oklahoma	966	347	320	47,450,757	147,924,291	43.86
Texas	1,582	496	422	67,875,744	252,176,368	33.79
Mountain	1,601	745	627	121,514,552	268,160,368	35.61
Montana	431	194	178	30,217,135	73,618,242	47.72
Idaho	227	106	94	20,005,947	44,513,900	47.62
Wyoming	160	72	64	11,963,364	26,390,048	41.29
Colorado	404	192	163	30,452,646	66,317,753	31.34
New Mexico	124	55	37	6,692,874	16,052,302	34.89
Arizona	88	55	32	11,419,992	20,032,210	33.51
Utah	133	54	48	7,396,882	14,727,010	14.84
Nevada	34	17	11	3,365,712	6,508,903	26.19
Pacific	1,407	789	599	149,824,526	207,514,044	11.16
Washington	401	201	149	28,756,973	48,427,865	17.41
Oregon	278	149	126	29,285,554	39,904,738	20.38
California	728	439	324	91,781,999	119,181,441	8.60

THE ESTIMATED AMOUNT OF PERSONAL AND COLLATERAL LOANS TO FARMERS.

It may be observed from Table 1 that 45 per cent of the banks in the United States complied with the request for information. Owing to lack of classified data concerning total loans and discounts, it was not found possible to make separate estimates for city and country banks. It should be stated in this connection, however, that examination showed that the percentage of replies from banks located in larger cities was almost uniformly higher than from the country banks of the same States. With this fact in mind, it is interesting to note the percentage of banks which reported farm business. For the United States as a whole, 76 per cent of the banks reporting had some farm business. In the West South Central States, the corresponding figure was 88 per cent, and the lowest reported for any geographic division was 45 per cent for the New England States. By States, the five highest percentages were as follows: Arkansas, 95 per cent; Oklahoma and Montana, 92 per cent each, and Kansas and North Dakota, 91 per cent each.

The amount of farmers' personal and collateral loans actually reported is in itself significant. Its chief value, however, is that it constitutes a basis for estimating the total amount of such loans outstanding with banks. In estimating this total, the reports from national banks and banks other than national were considered separately. It was assumed in the case of each class that the ratio of farmers' personal and collateral loans to total loans and discounts

obtained for the banks reporting was also applicable to the loans and discounts of the banks which did not report. In view of the fact that city banks, as explained above, were represented in the reports rather more largely than country banks, it would seem that the estimates arrived at on this basis should be conservative rather than the reverse.

The prominence of agriculture in the West North Central States is apparent from the figures in the column showing the estimated total personal and collateral loans outstanding to farmers. The seven States in this division have about 40 per cent of the total of such loans in the United States, and Iowa alone has over 10 per cent.

Turning to the percentage which personal and collateral loans to farmers constitute of total loans and discounts of banks in the various States, the highest figures again are found for the West North Central States. The three States showing highest percentages of such loans to farmers are South Dakota, North Dakota, and Kansas, where the figures are 67.98 per cent, 62.58 per cent, and 60.07 per cent, respectively.

It has been estimated that the banks of the United States on December 31, 1920, held approximately \$1,447,500,000 of farm mortgage loans.¹ Combining this figure with the estimated amount of personal and collateral loans as shown in the table, namely, \$3,869,891,415, it appears that last December the banks of the United States had total loans to farmers approximating \$5,317,400,000. This amount represented 18.3 per cent of the total loans and discounts of all banks. A similar combination of the percentages for the estimated totals of the two classes of loans indicates that the total bank accommodation to farmers constituted 78 per cent of the total loans and discounts of all banks in South Dakota; 77 per cent in North Dakota; 69 per cent in Kansas; and 68 per cent in Iowa.

SEASONAL FLUCTUATION IN PERSONAL AND COLLATERAL LOANS TO FARMERS.

It is generally known that in agricultural sections banks experience a gradually increasing demand for credit, which commences with the planting of crops and reaches a peak immediately prior to the time when crops are ready for market. Figure 1 indicates for the United States and for each of its geographic divisions the fluctuations which occurred during 1920 in the amount of farmers' personal and collateral loans outstanding with reporting banks. For the United States as a whole, there was a gradual increase for each month from January to October, when loans began to decline. It is apparent, however, that this decline was very slight, and that the contraction

¹ Department Bulletin No. 1047, entitled, "Farm Mortgage Loans by Banks, Insurance Companies and Other Agencies."

FLUCTUATIONS IN AMOUNT OF BANK LOANS TO FARMERS ON PERSONAL & COLLATERAL SECURITY

AS
REPORTED FOR THE LAST DAY OF EACH MONTH, 1920
JANUARY 31 = 100

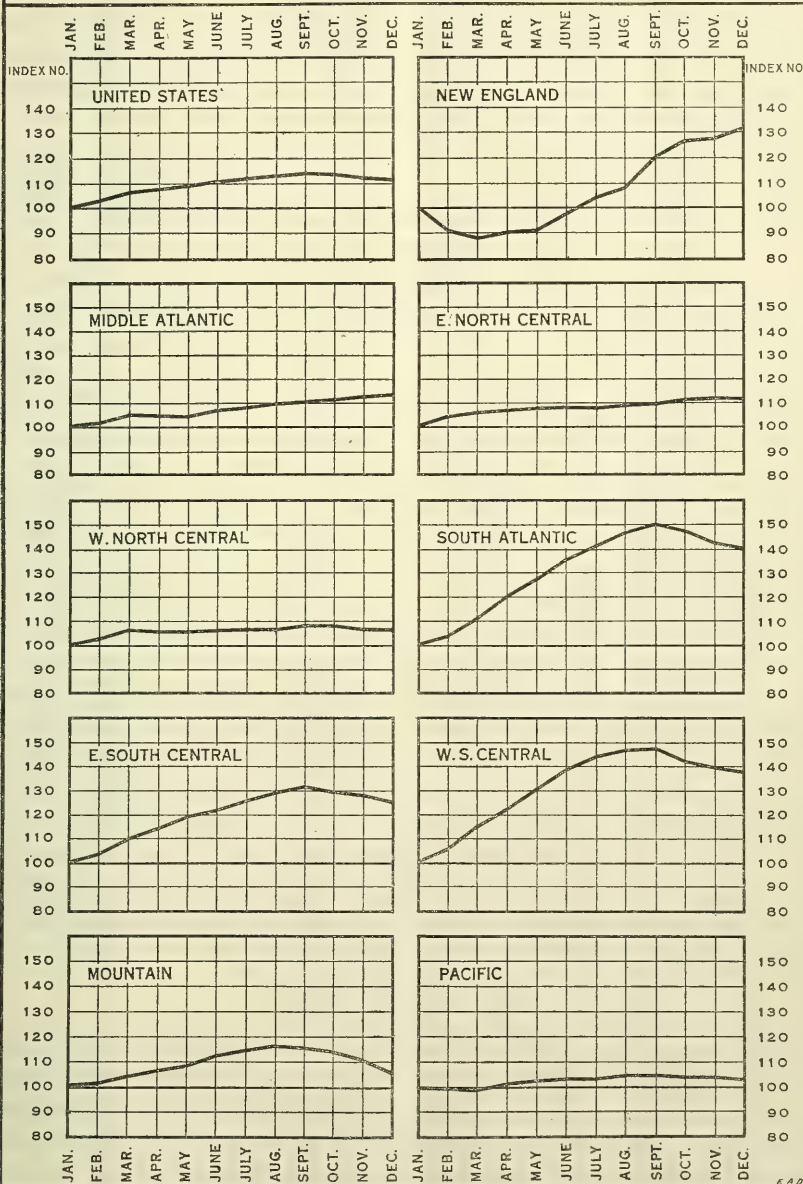


FIG. 1.—Fluctuations in loans.—Data based on reports from following number of banks: United States, 1930; New England, 19; Middle Atlantic, 128; East North Central, 339; West North Central, 840; South Atlantic, 128; East South Central, 91; West South Central, 198; Mountain, 121; Pacific, 100.

of outstanding debt during the last three months of the year was far less than those familiar with farm financial practice would normally expect. This feature of the diagram, therefore, emphasizes the fact that 1920 was decidedly an abnormal year.

For the New England States a rather unexpected curve occurs. In view of the importance of dairying and truck gardening in these States and the comparatively steady income from these activities, one would hardly expect a variation during the year of over 40 points. In only two geographic divisions, namely, the South Atlantic and the West South Central, was a greater variation shown. It may also be noted that for New England and also for the Middle Atlantic division the curves continue upward, and reach their peaks in December. This fact would lead one to believe that the banks in these two sections were in a position to continue extending credit for a longer time after the arrival of the credit stringency than was the case elsewhere.

In the East North Central, West North Central, and Pacific divisions the amounts outstanding were remarkably uniform during the entire year. This fact is no doubt accounted for, at least in part, by the diversified farming which is practiced in these three sections, but perhaps also by the fact that toward the end of the season farmers found it difficult, and in some cases impossible, to obtain the credit they desired and needed. In the South Atlantic, East South Central, and West South Central divisions the fluctuations were marked. In these areas a great deal of money is borrowed for the purchase of fertilizer and for food and feed during the crop-producing season. The credit curves, therefore, begin to rise at once, and continue upward until October. During October, November, and December a slight decrease is shown, which, however, doubtless falls far short of amounting to a normal contraction. The Mountain division has what appears to be more nearly a normal curve. The peak for the Mountain division came in August. During the last four months of 1920 there was a marked contraction of loans in this area, reflecting in part, no doubt, a rapid marketing of live stock.

RATES OF INTEREST.

The average low, high, and prevailing rates of interest for short-time loans to farmers as reported by the banks are shown in Table 2, loans of \$100 or more and loans of less than \$100 being classified separately. In examining these rates it should be kept in mind that the reports were received mainly during March, 1921, which was approximately the peak for interest rates throughout the United States. An average prevailing rate of 7.96 per cent on short-time loans of \$100 or more is indeed high. However, as compared with the rates of

discount on agricultural as well as other credit paper, which for the month in question averaged approximately 7 per cent, the rate reported is perhaps no higher than the banks were forced to charge in order to continue in operation.

TABLE 2.—Average rates of interest on short-time loans to farmers reported by banks, March, 1921.

Geographic division, State, and crop estimates district.	Short-time loans of \$100 or more.				Petty short-time loans.			
	Number of banks report- ing.	Rate of interest.			Number of banks report- ing.	Rate of interest.		
		Low.	High.	Prevail- ing.		Low.	High.	Prevail- ing.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
United States..	9,157	7.59	8.23	7.96	7,880	7.91	8.48	8.21
New England.....	226	6.19	6.57	6.43	153	6.31	6.59	6.49
Maine.....	42	6.12	6.40	6.31	29	6.34	6.62	6.50
New Hampshire.....	28	5.89	6.00	5.98	18	5.94	6.00	6.00
Vermont.....	31	6.00	6.10	6.03	27	6.04	6.15	6.07
Massachusetts.....	77	6.43	7.09	6.86	46	6.66	7.14	6.97
Rhode Island.....	5	6.50	7.10	7.00	4	6.75	7.25	7.25
Connecticut.....	43	6.13	6.44	6.31	29	6.16	6.38	6.31
Middle Atlantic.....	675	5.97	6.03	6.01	560	5.98	6.03	6.00
New York.....	259	5.98	6.05	6.01	212	5.99	6.06	6.01
District 2.....	17	6.00	6.00	6.00	15	6.00	6.00	6.00
3.....	6	6.00	6.00	6.00	4	6.00	6.00	6.00
4.....	50	5.98	6.12	6.02	43	6.01	6.10	6.03
5.....	51	5.99	6.00	6.00	43	6.00	6.00	6.00
6.....	28	6.00	6.00	6.00	24	6.00	6.04	6.00
7.....	26	6.00	6.19	6.06	24	6.00	6.29	6.02
8.....	11	6.00	6.00	6.00	9	6.00	6.00	6.00
9.....	48	5.98	6.04	6.02	35	6.00	6.00	6.00
9a.....	22	5.91	6.00	6.00	15	5.87	6.00	6.00
New Jersey.....	74	5.94	6.04	6.00	58	5.98	6.03	6.00
District 1.....	10	5.80	6.10	6.00	9	6.00	6.00	6.00
2.....	4	6.00	6.00	6.00	2	6.00	6.00	6.00
3.....	13	5.81	6.15	6.00	10	5.90	6.20	6.00
5.....	27	6.00	6.00	6.00	22	6.00	6.00	6.00
7.....	14	6.00	6.00	6.00	11	6.00	6.00	6.00
9.....	6	6.00	6.00	6.00	4	6.00	6.00	6.00
Pennsylvania.....	342	5.96	6.01	6.01	290	5.97	6.00	6.00
District 1.....	23	6.00	6.04	6.02	20	6.00	6.00	6.00
2.....	26	6.00	6.00	6.00	26	6.00	6.00	6.00
3.....	21	6.00	6.00	6.00	18	6.00	6.00	6.00
4.....	34	6.00	6.00	6.00	27	6.00	6.00	6.00
5.....	56	5.95	6.00	6.00	47	5.98	6.02	6.00
6.....	28	5.93	6.00	6.00	25	6.00	6.00	6.00
7.....	46	5.93	6.00	6.00	38	5.92	6.00	6.00
8.....	38	5.89	6.00	6.00	35	5.94	6.00	6.00
9.....	70	5.96	6.04	6.04	54	5.96	6.00	5.99
East North Central...	1,890	6.58	7.23	6.96	1,666	6.88	7.40	7.17
Ohio.....	370	6.48	7.09	6.79	329	6.75	7.25	7.00
District 1.....	66	6.54	7.39	7.00	59	6.98	7.56	7.36
2.....	37	6.41	6.65	6.59	35	6.57	6.80	6.69
3.....	59	6.46	7.03	6.81	49	6.67	7.20	6.93
4.....	38	6.66	7.32	6.92	32	6.81	7.47	6.98
5.....	50	6.56	7.34	6.85	49	6.92	7.43	7.15
6.....	35	6.29	6.60	6.43	29	6.34	6.69	6.45
7.....	39	6.47	6.91	6.68	34	6.59	7.18	6.86
8.....	17	6.53	7.41	7.03	18	7.00	7.61	7.50
9.....	29	6.28	7.03	6.66	24	6.71	7.12	6.94

TABLE 2.—Average rates of interest on short-time loans to farmers reported by banks, March, 1921—Continued.

Geographic division, State, and crop estimates district.	Short-time loans of \$100 or more.				Number of banks report- ing.	Petty short-time loans.		
	Number of banks report- ing.	Rate of interest.				Rate of interest.		
		Low.	High.	Prevail- ing.		Low.	High.	Prevail- ing.
East North Central— Continued. Indiana.....	384	<i>Per cent.</i> 6.82	<i>Per cent.</i> 7.64	<i>Per cent.</i> 7.27	335	<i>Per cent.</i> 7.26	<i>Per cent.</i> 7.79	<i>Per cent.</i> 7.55
District 1.....	34	6.91	7.56	7.32	26	7.04	7.46	7.23
2.....	50	6.98	7.76	7.46	46	7.41	7.91	7.70
3.....	44	7.00	7.68	7.41	39	7.49	7.87	7.73
4.....	46	6.86	7.84	7.38	46	7.30	7.85	7.54
5.....	85	6.87	7.78	7.40	73	7.20	7.88	7.61
6.....	27	6.83.	7.37	7.11	26	7.12	7.58	7.33
7.....	51	6.63	7.65	7.16	40	7.52	7.90	7.75
8.....	26	6.50	7.35	6.85	20	6.95	7.60	7.22
9.....	21	6.38	7.14	6.71	19	6.84	7.47	7.21
Illinois.....	519	6.56	6.98	6.83	428	6.67	7.07	6.95
District 1.....	71	6.46	6.98	6.80	60	6.52	6.99	6.85
2.....	74	6.50	7.00	6.72	69	6.43	6.87	6.72
3.....	58	6.57	6.88	6.82	56	6.64	6.91	6.88
4.....	73	6.44	6.91	6.80	62	6.55	6.92	6.81
4 a.....	57	6.61	6.95	6.84	45	6.73	6.96	6.88
5.....	61	6.70	6.98	6.96	46	6.79	7.02	6.95
6.....	63	6.71	7.02	6.94	45	6.80	7.17	7.09
6 a.....	42	6.37	6.98	6.67	34	7.00	7.35	7.09
7.....	20	6.90	7.40	7.10	11	7.55	10.00	9.27
Michigan.....	244	6.76	7.17	6.97	221	7.00	7.60	7.28
District 1.....	21	6.91	7.95	7.31	18	7.39	9.61	8.22
2.....	21	6.71	7.09	6.90	18	6.89	7.06	7.06
3.....	6	7.00	7.00	7.00	7	8.29	9.00	8.64
4.....	6	6.83	7.17	6.83	6	6.83	7.17	7.00
5.....	23	7.00	7.17	7.11	18	7.00	8.22	7.53
6.....	27	6.96	7.78	7.37	26	7.44	8.15	7.94
7.....	40	6.71	6.99	6.85	37	6.84	7.08	6.93
8.....	47	6.57	6.94	6.80	44	6.66	6.98	6.89
9.....	53	6.70	6.98	6.85	47	6.94	7.11	7.01
Wisconsin.....	373	6.64	7.31	7.02	353	6.81	7.45	7.18
District 1.....	68	7.22	8.03	7.69	65	7.38	8.18	7.85
2.....	33	6.97	7.58	7.42	33	7.36	8.06	7.71
3.....	19	6.89	7.79	7.29	19	7.21	8.00	7.55
4.....	37	6.68	7.50	7.03	38	6.95	7.55	7.25
5.....	30	6.45	7.22	6.80	28	6.57	7.43	7.02
6.....	80	6.38	6.84	6.67	70	6.42	6.89	6.73
7.....	28	6.50	7.25	6.96	26	6.62	7.31	7.13
8.....	41	6.38	6.93	6.76	37	6.49	7.00	6.85
9.....	37	6.20	6.85	6.57	37	6.31	6.91	6.63
West North Central.....	3,044	8.04	8.82	8.50	2,660	8.33	8.96	8.71
Minnesota.....	541	7.89	8.84	8.41	503	8.29	9.00	8.62
District 1.....	87	8.78	9.82	9.44	80	8.96	9.92	9.57
2.....	28	8.82	9.79	9.32	28	9.25	9.93	9.55
3.....	12	7.75	8.75	8.21	11	8.09	8.82	8.64
4.....	65	8.05	9.14	8.57	59	8.42	9.44	9.00
5.....	88	7.72	8.62	8.19	85	8.05	8.84	8.48
6.....	66	7.67	8.75	8.22	58	8.02	8.82	8.54
7.....	57	8.07	8.92	8.52	50	8.10	9.07	8.64
8.....	72	7.54	8.28	7.97	65	7.70	8.53	8.07
9.....	66	6.90	7.81	7.42	66	7.17	7.92	7.53
Iowa.....	566	7.35	7.89	7.71	496	7.51	7.92	7.79
District 1.....	64	7.78	8.00	7.95	51	7.89	8.00	7.96
2.....	65	7.62	7.97	7.88	61	7.69	8.02	7.94
3.....	60	7.10	7.85	7.58	54	7.49	7.93	7.83
4.....	66	7.73	7.98	7.94	61	7.74	7.98	7.93
5.....	83	7.41	8.00	7.83	65	7.61	8.00	7.89
6.....	78	6.65	7.65	7.25	68	6.85	7.73	7.36
7.....	44	7.73	7.98	7.93	37	7.85	7.97	7.96
8.....	46	7.52	8.00	7.93	41	7.73	8.00	7.95
9.....	60	6.85	7.58	7.23	55	7.05	7.69	7.43

TABLE 2.—Average rates of interest on short-time loans to farmers reported by banks, March, 1921—Continued.

Geographic division, State, and crop estimates district.	Short-time loans of \$100 or more.				Number of banks report- ing.	Petty short-time loans.		
	Number of banks report- ing.	Rate of interest.				Rate of interest.		
		Low.	High.	Prevail- ing.		Low.	High.	Prevail- ing.
West North Central— Continued. Missouri.....	447	<i>Per cent.</i> 7.38	<i>Per cent.</i> 7.95	<i>Per cent.</i> 7.72	373	<i>Per cent.</i> 7.72	<i>Per cent.</i> 8.33	<i>Per cent.</i> 8.03
District 1.....	72	7.32	7.81	7.62	57	7.53	7.86	7.78
2.....	52	7.31	7.88	7.69	35	7.60	7.91	7.80
3.....	39	7.08	7.77	7.45	36	7.31	7.92	7.67
4.....	66	7.42	7.94	7.77	53	7.85	8.32	8.12
5.....	68	7.38	7.90	7.74	58	7.73	8.16	7.98
6.....	46	6.65	7.53	7.20	47	7.15	7.72	7.53
7.....	38	7.87	8.13	8.00	30	8.23	9.07	8.40
8.....	38	7.84	8.87	8.34	30	8.53	10.97	9.53
9.....	28	7.86	8.11	7.93	27	8.07	8.15	8.07
North Dakota.....	368	9.38	9.95	9.82	341	9.95	9.95	9.86
District 1.....	53	9.74	10.00	9.92	51	9.86	9.98	9.94
2.....	52	9.69	10.00	9.98	49	9.80	10.00	9.96
3.....	71	8.92	9.86	9.33	65	9.11	9.88	9.71
4.....	32	10.00	10.00	10.00	30	10.00	10.00	10.00
5.....	32	9.12	9.94	9.84	27	9.41	9.89	9.78
6.....	41	8.63	9.80	9.40	39	9.08	9.85	9.58
7.....	25	9.76	10.00	9.92	22	9.95	10.00	10.00
8.....	22	9.77	10.00	9.95	20	9.80	10.00	10.00
9.....	40	9.32	10.00	9.94	38	9.45	10.00	9.96
South Dakota.....	261	8.97	9.98	9.59	238	9.20	10.05	9.69
District 1.....	19	10.26	10.68	10.68	18	10.33	10.78	10.78
2.....	43	9.05	9.98	9.56	39	9.38	10.10	9.64
3.....	54	8.81	10.19	9.75	49	8.89	10.16	9.77
4.....	18	9.39	9.94	9.61	17	9.82	9.82	9.82
5.....	25	9.12	10.08	9.70	21	9.62	10.19	9.90
6.....	55	8.25	9.64	9.01	48	8.50	9.81	9.20
7.....	5	9.60	10.00	10.00	5	9.60	10.00	10.00
8.....	14	10.14	10.43	10.21	14	10.14	10.71	10.36
9.....	28	8.57	9.50	9.21	27	8.70	9.37	9.15
Nebraska.....	365	8.24	9.35	8.87	304	8.66	9.51	9.12
District 1.....	16	9.25	10.00	9.78	17	9.71	10.00	9.88
2.....	13	9.46	10.00	9.92	12	9.42	10.00	10.00
3.....	55	8.38	9.58	9.18	47	8.72	9.79	9.37
4.....	23	9.87	10.00	10.00	20	10.00	10.00	10.00
5.....	45	8.08	9.66	8.83	33	8.73	9.73	9.30
6.....	80	7.77	8.91	8.34	70	8.16	9.01	8.59
7.....	33	8.64	9.94	9.55	29	9.07	9.69	9.48
8.....	35	7.97	9.20	8.66	29	8.62	9.72	9.16
9.....	65	7.68	8.75	8.21	47	7.89	9.06	8.39
Kansas.....	496	7.97	8.81	8.37	405	8.16	9.13	8.75
District 1.....	27	8.30	9.26	8.93	21	9.14	9.62	9.52
2.....	54	7.87	8.63	8.11	46	8.15	8.96	8.45
3.....	76	7.46	8.25	7.84	63	7.85	8.58	8.16
4.....	17	8.76	9.47	9.29	14	8.93	9.57	9.21
5.....	65	8.03	8.63	8.31	52	8.19	8.88	8.43
6.....	64	7.72	8.34	8.09	51	8.20	8.88	8.50
7.....	35	9.14	9.83	9.51	30	7.51	9.80	9.53
8.....	80	7.87	9.11	8.51	64	8.56	9.52	9.08
9.....	78	7.96	8.85	8.30	64	8.59	9.25	8.94
South Atlantic.....	802	7.26	7.78	7.52	687	7.50	8.18	7.79
Delaware.....	14	6.00	6.00	6.00	13	6.00	6.00	6.00
Maryland.....	61	5.98	6.05	6.01	58	6.00	6.03	6.02
District 1.....	9	6.00	6.00	6.00	8	6.00	6.00	6.00
2.....	21	5.95	6.05	6.00	19	6.00	6.00	6.00
3.....	7	6.00	6.00	6.00	8	6.00	6.00	6.00
5.....	11	6.00	6.18	6.09	12	6.00	6.17	6.08
6.....	7	6.00	6.00	6.00	7	6.00	6.00	6.00
8.....	1	6.00	6.00	6.00	.....	.....	.....	.....
9.....	5	6.00	6.00	6.00	5	6.00	6.00	6.00

TABLE 2.—Average rates of interest on short-time loans to farmers reported by banks, March, 1921—Continued.

Geographic division, State, and crop estimates district.	Short-time loans of \$100 or more.				Petty short-time loans.			
	Number of banks report- ing.	Rate of interest.			Number of banks report- ing.	Rate of interest.		
		Low.	High.	Prevail- ing.		Low.	High.	Prevail- ing.
		Per cent.	Per cent.	Per cent.		Per cent.	Per cent.	Per cent.
South Atlantic—Con. District of Columbia	2	6.00	8.00	6.50	1	6.00	8.00	8.00
Virginia.....	111	6.06	6.27	6.17	99	6.20	6.39	6.29
District 2.....	17	6.00	6.00	6.00	16	6.00	6.00	6.00
4.....	14	6.00	6.00	6.00	12	6.00	6.00	6.00
5.....	17	6.00	6.00	6.00	14	6.00	6.00	6.00
6.....	13	6.00	6.00	6.00	12	6.00	6.00	6.00
7.....	26	6.02	6.10	6.02	22	6.20	6.48	6.34
8.....	10	6.20	6.70	6.60	10	6.30	6.80	6.70
9.....	14	6.29	7.43	6.89	13	6.46	7.54	7.12
West Virginia.....	55	6.00	6.11	6.05	42	6.00	6.19	6.10
District 1.....	9	6.00	6.00	6.00	5	6.00	6.00	6.00
2.....	12	6.00	6.00	6.00	10	6.00	6.00	6.00
3.....	9	6.00	6.22	6.00	6	6.00	6.33	6.00
4.....	9	6.00	6.44	6.33	6	6.00	7.00	6.67
5.....	2	6.00	6.00	6.00	2	6.00	6.00	6.00
6.....	10	6.00	6.00	6.00	9	6.00	6.00	6.00
8.....	4	6.00	6.00	6.00	4	6.00	6.00	6.00
North Carolina.....	106	6.12	6.44	6.23	83	6.10	6.65	6.28
District 1.....	12	6.00	6.75	6.38	9	6.00	8.22	6.78
2.....	14	6.00	6.00	6.00	12	6.00	6.00	6.00
3.....	17	6.12	6.24	6.12	14	6.14	6.26	6.29
4.....	12	6.17	6.17	6.17	10	6.20	6.40	6.30
5.....	20	6.00	6.30	6.05	15	6.00	6.40	6.07
6.....	11	6.00	6.18	6.00	9	6.00	6.00	6.00
7.....	6	6.67	7.67	7.33	3	7.00	8.67	8.33
8.....	10	6.50	7.40	6.65	9	6.11	7.33	6.17
9.....	4	6.00	6.00	6.00	2	6.00	6.00	6.00
South Carolina.....	172	7.87	8.11	8.06	147	8.04	8.37	8.20
District 1.....	37	7.89	8.08	8.03	38	7.95	8.45	8.08
2.....	19	7.42	8.00	8.00	17	7.59	8.35	8.12
3.....	28	8.07	8.14	8.07	23	8.17	8.35	8.17
4.....	23	7.91	8.09	8.09	19	7.89	8.11	8.11
5.....	30	7.87	8.20	8.07	23	8.17	8.35	8.26
6.....	9	7.89	8.00	7.94	7	8.00	8.00	8.00
8.....	26	7.92	8.15	8.15	20	8.48	8.70	8.62
Georgia.....	231	8.47	9.54	8.94	206	8.91	10.35	9.49
District 1.....	13	8.00	9.08	8.46	12	8.67	10.29	9.04
2.....	27	8.22	9.33	8.70	27	8.67	11.33	9.65
3.....	22	8.18	9.00	8.55	18	8.22	9.11	8.56
4.....	54	8.28	9.41	8.80	40	8.68	9.52	9.13
5.....	35	8.51	9.91	9.25	31	9.23	11.19	10.13
6.....	26	9.04	10.19	9.52	23	9.48	10.43	9.70
7.....	20	8.45	9.30	8.75	20	8.85	9.90	9.10
8.....	21	9.05	10.38	9.57	21	9.62	11.05	10.52
9.....	13	7.92	8.62	8.46	14	8.57	10.00	9.00
Florida.....	50	8.06	9.12	8.72	38	8.74	9.84	9.32
District 1.....	7	9.14	10.00	9.57	4	9.50	10.00	9.50
3.....	9	8.33	9.78	9.22	6	9.00	10.75	10.00
5.....	25	8.16	8.56	8.24	20	8.40	9.50	8.95
8.....	9	8.44	9.33	8.89	8	9.00	10.00	9.62
East South Central.....	599	7.52	8.09	7.83	512	8.06	8.60	8.36
Kentucky.....	131	6.50	7.08	6.79	103	6.85	7.48	7.14
District 1.....	18	6.78	7.61	7.28	14	7.29	8.29	7.71
2.....	24	6.25	6.96	6.69	16	6.75	7.31	7.00
3.....	4	6.00	6.00	6.00	4	6.00	6.00	6.00
5.....	32	6.19	6.47	6.28	26	6.46	6.77	6.63

TABLE 2.—Average rates of interest on short-time loans to farmers reported by banks, March, 1921—Continued.

Geographic division, State, and crop estimates district.	Short-time loans of \$100 or more.			Petty short-time loans.				
	Number of banks report- ing.	Rate of interest.			Number of banks report- ing.	Rate of interest.		
		Low.	High.	Prevail- ing.		Low.	High.	Prevail- ing.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
East South Central— Continued.								
Kentucky—Con.								
District 6.....	6	6.67	7.33	7.00	3	6.00	7.33	6.67
7.....	17	7.06	7.76	7.47	15	7.23	7.77	7.57
7a.....	14	6.93	7.71	7.14	11	7.36	8.55	7.73
8.....	12	6.42	6.92	6.58	12	7.00	7.58	7.25
9.....	4	6.00	6.50	6.25	2	6.00	7.00	6.50
Tennessee.....	186	7.39	8.13	7.88	150	7.87	8.43	8.25
District 1.....	29	8.07	8.62	8.48	26	8.46	8.77	8.65
2.....	27	6.89	7.67	7.26	20	7.10	8.15	7.70
3.....	23	6.96	7.87	7.48	17	7.06	7.76	7.53
4.....	19	7.89	9.00	8.63	16	8.75	9.25	9.12
5.....	35	7.00	7.83	7.54	28	7.57	8.29	8.00
6.....	10	7.20	7.80	7.80	9	7.78	8.11	8.00
7.....	15	7.53	8.33	8.13	11	8.55	8.91	8.82
8.....	14	7.57	8.14	8.00	9	7.78	8.22	8.00
9.....	14	7.71	8.00	8.00	14	8.07	8.86	8.50
Alabama.....	140	8.15	8.88	8.46	126	9.08	9.84	9.51
District 1.....	12	7.83	8.17	8.00	11	9.91	9.91	9.91
2.....	16	8.25	9.00	8.62	17	8.76	9.82	9.53
2 a.....	15	8.17	9.13	8.62	14	9.00	10.00	9.50
3.....	14	8.43	8.86	8.64	11	9.82	10.00	9.82
4.....	12	8.00	8.50	8.17	12	8.67	9.00	9.00
5.....	11	8.18	8.73	8.36	9	9.11	9.56	9.56
6.....	19	8.21	9.68	8.95	18	9.11	10.44	9.78
7.....	4	8.50	8.50	8.50	4	10.00	10.00	10.00
8.....	15	8.13	8.80	8.33	12	9.17	9.83	9.58
9.....	22	8.00	8.73	8.23	18	8.44	9.67	8.94
Mississippi.....	142	8.01	8.17	8.11	133	8.24	8.50	8.34
District 1.....	15	8.13	8.13	8.13	15	8.27	8.53	8.27
2.....	23	8.17	8.35	8.22	22	8.18	8.64	8.32
3.....	9	8.00	8.22	8.00	7	8.00	8.29	8.00
4.....	12	8.00	8.17	8.08	12	7.83	8.33	8.17
5.....	20	8.10	8.30	8.25	19	8.63	8.84	8.79
6.....	13	8.00	8.00	8.00	13	8.62	8.77	8.62
7.....	21	7.81	8.10	8.10	17	8.12	8.12	8.12
8.....	14	8.00	8.00	8.00	14	8.43	8.43	8.43
9.....	15	7.87	8.13	8.00	14	7.86	8.29	8.07
West South Central..	789	9.24	9.90	9.66	621	9.80	10.53	10.14
Arkansas.....	112	9.15	9.92	9.70	102	9.64	9.95	9.88
District 1.....	17	9.24	9.94	9.35	15	9.80	9.93	9.93
2.....	16	9.25	10.00	9.81	11	9.82	10.00	9.91
3.....	19	8.95	10.00	9.89	18	9.77	10.00	9.89
4.....	16	9.25	9.75	9.75	15	9.73	9.87	9.87
5.....	6	9.67	10.00	9.67	6	10.00	10.00	10.00
6.....	14	8.86	9.71	9.43	13	9.08	9.85	9.62
7.....	11	9.32	10.00	9.95	11	9.64	10.00	10.00
8.....	6	9.67	10.00	9.83	6	10.00	10.00	10.00
9.....	7	8.14	10.00	9.71	7	8.86	10.00	9.86
Louisiana.....	49	7.89	8.74	8.34	45	8.38	9.27	8.74
District 1.....	4	7.75	8.50	7.88	4	7.75	9.00	8.38
2.....	6	8.00	9.83	8.67	6	9.00	9.83	9.42
3.....	7	8.29	9.14	8.86	6	8.33	9.33	9.00
4.....	3	8.00	8.67	8.17	3	8.00	8.67	8.17
5.....	9	8.00	8.22	8.11	9	8.89	9.11	9.00
6.....	3	8.00	8.67	8.67	3	8.00	8.67	8.67
7.....	9	7.33	8.67	8.22	8	8.25	10.00	8.50
8.....	6	8.00	8.67	8.33	5	8.00	8.80	8.40
9.....	2	7.75	7.75	7.75	1	8.00	8.00	8.00

TABLE 2.—Average rates of interest on short-time loans to farmers reported by banks, March, 1921. —Continued.

Geographic division, State, and crop estimates district.	Short-time loans of \$100 or more.				Petty short-time loans.			
	Number of banks report- ing.	Rate of interest.			Number of banks report- ing.	Rate of interest.		
		Low.	High.	Prevail- ing.		Low.	High.	Prevail- ing.
West South Central— Continued. Oklahoma.....	274	<i>Per cent.</i> 9.46	<i>Per cent.</i> 9.99	<i>Per cent.</i> 9.84	204	<i>Per cent.</i> 10.11	<i>Per cent.</i> 10.79	<i>Per cent.</i> 10.40
District 1.....	35	9.74	10.06	10.00	25	9.92	10.08	10.00
2.....	33	8.85	9.76	9.45	23	9.57	10.09	9.78
3.....	20	9.40	9.90	9.70	17	9.65	10.00	9.88
4.....	23	10.00	10.00	10.00	16	10.00	10.94	10.00
5.....	52	9.31	10.00	9.83	38	10.42	11.08	10.79
6.....	27	9.04	10.00	9.78	20	10.30	11.85	10.50
7.....	43	9.63	10.05	9.95	33	9.82	10.27	10.08
8.....	36	9.83	10.06	9.97	27	10.81	11.96	11.63
9.....	5	9.20	10.00	9.80	5	10.40	10.40	10.40
Texas.....	354	9.28	9.99	9.68	270	9.87	10.76	10.27
District 1.....	57	9.82	10.04	9.91	41	9.90	10.24	9.95
2.....	65	9.27	10.17	9.75	53	10.55	12.28	11.26
3.....	35	9.43	10.27	9.86	24	9.62	11.29	10.00
4.....	14	9.71	10.00	9.79	9	10.00	10.22	10.00
4a.....	36	9.56	9.94	9.83	33	9.91	10.24	10.06
5.....	76	8.92	9.97	9.63	57	9.46	10.26	10.02
6.....	17	9.29	10.00	9.68	12	10.92	12.25	12.08
8.....	41	9.05	9.63	9.33	28	9.36	9.86	9.64
9.....	13	8.05	9.38	8.69	13	9.31	9.69	9.31
Mountain.....	590	9.19	9.92	9.64	543	9.61	10.25	9.96
Montana.....	179	9.61	10.00	9.90	171	9.71	10.01	9.95
District 1.....	6	9.33	10.00	9.83	6	9.33	10.00	9.83
2.....	32	9.94	10.00	10.00	30	10.00	10.00	10.00
3.....	22	9.82	10.00	10.00	21	10.00	10.00	10.00
4.....	15	8.93	10.00	9.60	15	9.33	10.00	9.80
5.....	36	9.50	10.00	9.88	35	9.66	10.00	9.94
6.....	15	9.87	10.00	10.00	14	9.71	10.00	10.00
7.....	6	9.00	10.00	9.67	6	9.00	10.33	9.83
8.....	30	9.53	10.00	9.90	29	9.66	10.00	9.97
9.....	17	9.83	10.00	9.94	15	9.80	10.00	9.93
Idaho.....	91	9.02	9.77	9.55	86	9.48	9.93	9.76
District 1.....	23	8.57	9.26	8.91	22	9.05	9.82	9.27
2.....	3	9.33	10.00	10.00	3	9.33	10.00	10.00
3.....	2	10.00	10.00	10.00	2	10.00	10.00	10.00
4.....	7	9.00	9.86	9.57	7	9.43	10.00	9.64
5.....	11	9.09	10.00	9.77	11	9.64	10.00	10.00
6.....	20	9.10	9.90	9.65	18	9.56	9.89	9.89
7.....	13	9.54	10.00	10.00	13	10.00	10.00	10.00
8.....	12	8.92	9.92	9.71	10	9.40	10.00	10.00
Wyoming.....	57	9.26	10.25	9.72	50	9.96	10.86	10.26
District 1.....	11	9.82	10.36	10.00	11	10.36	11.09	10.55
2.....	7	9.43	10.86	10.29	5	10.40	12.00	11.00
3.....	5	10.40	11.20	10.80	5	11.20	12.00	11.60
4.....	3	9.67	10.33	9.67	3	10.67	10.67	10.67
5.....	6	8.67	10.00	9.50	5	9.20	9.60	9.60
6.....	6	9.33	10.00	10.00	6	9.67	10.33	10.00
7.....	3	8.00	10.00	8.67	3	8.67	10.67	8.67
8.....	6	8.50	9.83	9.00	4	9.00	10.25	9.50
9.....	10	9.00	9.80	9.20	8	9.75	10.75	10.00
Colorado.....	153	8.91	9.67	9.43	134	9.41	10.12	9.84
District 1.....	7	9.29	10.00	9.71	7	10.00	10.29	10.14
2.....	36	8.21	9.19	8.74	30	8.70	9.33	9.13
3.....	18	9.33	10.00	9.89	17	9.88	10.12	10.00
4.....	18	9.33	10.28	9.67	18	10.00	10.89	10.22
5.....	6	8.00	9.67	8.83	5	8.40	10.40	9.40
6.....	28	8.86	9.59	9.32	23	9.04	9.83	9.65
7.....	5	9.20	10.80	9.60	5	9.60	10.80	10.40
8.....	11	9.27	10.73	9.82	9	10.00	11.33	10.67
9.....	24	9.25	10.08	9.91	20	9.70	10.10	10.10

TABLE 2.—Average rates of interest on short-time loans to farmers reported by banks, March, 1921—Continued.

Geographic division, State, and crop estimates district.	Short-time loans of \$100 or more.				Petty short-time loans.			
	Number of banks report- ing.	Rate of interest.			Number of banks report- ing.	Rate of interest.		
		Low.	High.	Prevail- ing.		Low.	High.	Prevail- ing.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Mountain—Contd. New Mexico.....	35	9.60	10.69	10.17	29	10.21	11.45	10.62
District 1.....	3	10.00	10.00	10.00	3	10.67	12.00	12.00
2.....	3	8.00	12.00	10.00	3	8.67	11.33	10.67
3.....	2	9.00	12.00	11.00	2	11.00	16.00	11.50
4.....	1	10.00	10.00	10.00				
5.....	3	8.00	10.67	9.00	3	9.33	10.67	9.33
6.....	14	10.00	10.57	10.29	10	10.60	11.00	10.60
7.....	2	10.00	11.00	10.50	2	11.00	12.00	11.00
8.....	5	10.00	10.40	10.40	4	10.00	11.00	10.25
9.....	2	10.00	10.00	10.00	2	10.00	10.00	10.00
Arizona.....	25	9.04	9.84	9.44	24	9.33	9.92	9.75
District 1.....								
2.....	2	10.00	10.00	10.00	1	10.00	10.00	10.00
3.....	2	10.00	10.00	10.00	2	10.00	10.00	10.00
5.....	13	8.31	9.69	9.00	12	9.00	9.83	9.58
6.....	2	10.00	10.00	10.00	3	10.00	10.00	10.00
7.....	2	10.00	10.00	10.00	2	9.00	10.00	10.00
8.....								
9.....	4	9.50	10.00	9.75	4	9.50	10.00	9.75
Utah.....	40	8.52	9.95	9.25	39	9.67	11.03	10.27
District 1.....	3	9.67	10.00	10.00	3	10.00	10.67	10.00
2.....	15	8.20	9.93	9.00	15	9.33	10.93	10.17
3.....	4	9.00	10.00	9.25	3	10.00	11.33	10.67
4.....	3	8.00	10.00	9.00	3	9.33	10.67	10.00
5.....	7	8.57	9.71	9.00	7	9.71	10.86	10.29
6.....	3	8.33	10.67	9.67	3	9.67	11.33	9.67
7.....	3	9.00	9.67	9.67	3	11.33	11.33	11.33
8.....	2	8.50	10.00	10.00	2	9.00	12.00	10.50
9.....								
Nevada.....	10	8.40	9.40	8.90	10	8.50	10.00	9.50
District 1.....	1	8.00	12.00	10.00	1	8.00	12.00	12.00
2.....	2	8.00	9.00	8.50	2	8.00	9.00	8.50
3.....	1	8.00	8.00	8.00	1	8.00	8.00	8.00
4.....	2	8.00	8.00	8.00	2	8.00	10.00	9.00
5.....	1	8.00	8.00	8.00	1	8.00	10.00	8.00
6.....	2	8.00	10.00	9.00	2	10.00	10.00	10.00
7.....								
8.....	1	12.00	12.00	12.00	1	8.00	12.00	12.00
9.....								
Pacific.....	542	7.61	8.35	8.01	478	8.01	8.62	8.24
Washington.....	134	8.22	8.91	8.56	123	8.60	9.28	8.90
District 1.....	18	7.83	8.11	8.00	17	8.24	8.47	8.29
2.....	13	9.08	10.46	9.85	13	9.54	10.77	10.15
3.....	7	8.29	10.29	8.86	7	9.00	10.57	9.57
4.....	15	7.73	8.33	8.00	14	8.21	8.71	8.43
5.....	11	8.00	8.64	8.45	11	8.27	9.00	8.64
5a.....	18	9.17	9.72	9.44	15	9.73	10.00	9.80
6.....	25	7.80	8.56	8.08	22	8.23	9.18	8.73
7.....	14	8.07	8.43	8.21	13	8.08	8.85	8.31
8.....	6	9.17	9.67	9.67	4	9.00	9.50	9.50
9.....	7	7.57	7.86	7.86	7	8.14	8.14	8.14
- Oregon.....	124	7.88	8.55	8.27	111	8.28	8.73	8.47
District 1.....	46	7.67	8.30	8.01	38	8.16	8.66	8.33
2.....	14	7.86	8.29	8.11	12	8.17	8.33	8.21
3.....	9	8.33	9.33	9.00	8	9.25	9.75	9.38
4.....	16	7.50	8.38	8.12	16	7.94	8.38	8.19
5.....	5	8.80	8.80	8.80	4	9.00	9.00	9.00
6.....	5	8.00	8.80	8.00	5	8.00	8.40	8.00
7.....	15	7.87	8.40	8.27	14	8.00	8.57	8.50
8.....	8	7.62	8.75	8.12	8	8.00	8.75	8.12
9.....	6	9.33	10.00	9.83	6	9.67	10.00	9.83

TABLE 2.—Average rates of interest on short-time loans to farmers reported by banks, March, 1921—Continued.

Geographic division, State, and crop estimates district.	Short-time loans of \$100 or more.				Petty short-time loans.			
	Number of banks report- ing.	Rate of interest.			Number of banks report- ing.	Rate of interest.		
		Low.	High.	Prevail- ing.		Low.	High.	Prevail- ing.
Pacific—Continued.		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
California.....	284	7.21	8.00	7.63	244	7.59	8.25	7.79
District 1.....	13	7.23	8.15	7.58	9	7.22	8.89	7.78
2.....	5	7.80	8.20	8.00	5	7.80	8.20	8.00
3.....	3	7.67	8.67	8.00	3	8.00	8.67	8.67
4.....	38	6.79	7.71	7.32	32	6.97	7.69	7.30
5.....	48	7.02	7.81	7.36	41	7.59	8.24	7.85
5a.....	55	7.39	7.93	7.76	50	7.66	8.04	7.87
6.....	6	7.50	8.83	7.67	8	7.00	8.50	7.50
6a.....	2	8.50	9.50	8.50	2	10.00	10.00	10.00
8.....	114	7.26	8.10	7.75	94	7.78	8.42	7.84

Considering the average prevailing rate on short-time loans of \$100 or more by geographic divisions, the lowest average is found for the Middle Atlantic States, namely, 6.01 per cent, and the highest for the West South Central States, 9.66 per cent. For individual States the lowest average is 5.98 per cent for New Hampshire, and the highest is 10.17 per cent for New Mexico. The smallest variation in the prevailing rate within any geographic division occurs in the Middle Atlantic States, where New Jersey has an average of 6 per cent and New York and Pennsylvania each 6.01 per cent. In the South Atlantic States, however, a variation of 2.72 per cent occurs between Delaware and Florida. For individual States, the largest variations in prevailing rates appear in Minnesota and Nevada. In Minnesota 9.44 per cent is the average for the northwest corner of the State and 7.42 per cent for the southeastern district. In Nevada three districts have an average rate of 8 per cent, while one district, the eighth, has an average of 12 per cent. The reasons for sectional variations in interest rates are discussed in an earlier bulletin.²

For the country as a whole, the difference between average prevailing rates on short-time loans of \$100 or more and petty loans is only twenty-five hundredths of 1 per cent. In general, this variation is largest in the South Central States where the credit needs of the small tenant farmers are a marked feature of the rural credit situation.

The districts which have been referred to in these paragraphs are indicated by number on the map, figure 2. By means of shading, this map also shows the approximate prevailing rate on personal and collateral loans of \$100 or more in each such district.

² Department Bulletin 409, "Factors Affecting Interest Rates and Other Charges on Short-Time Farm Loans."

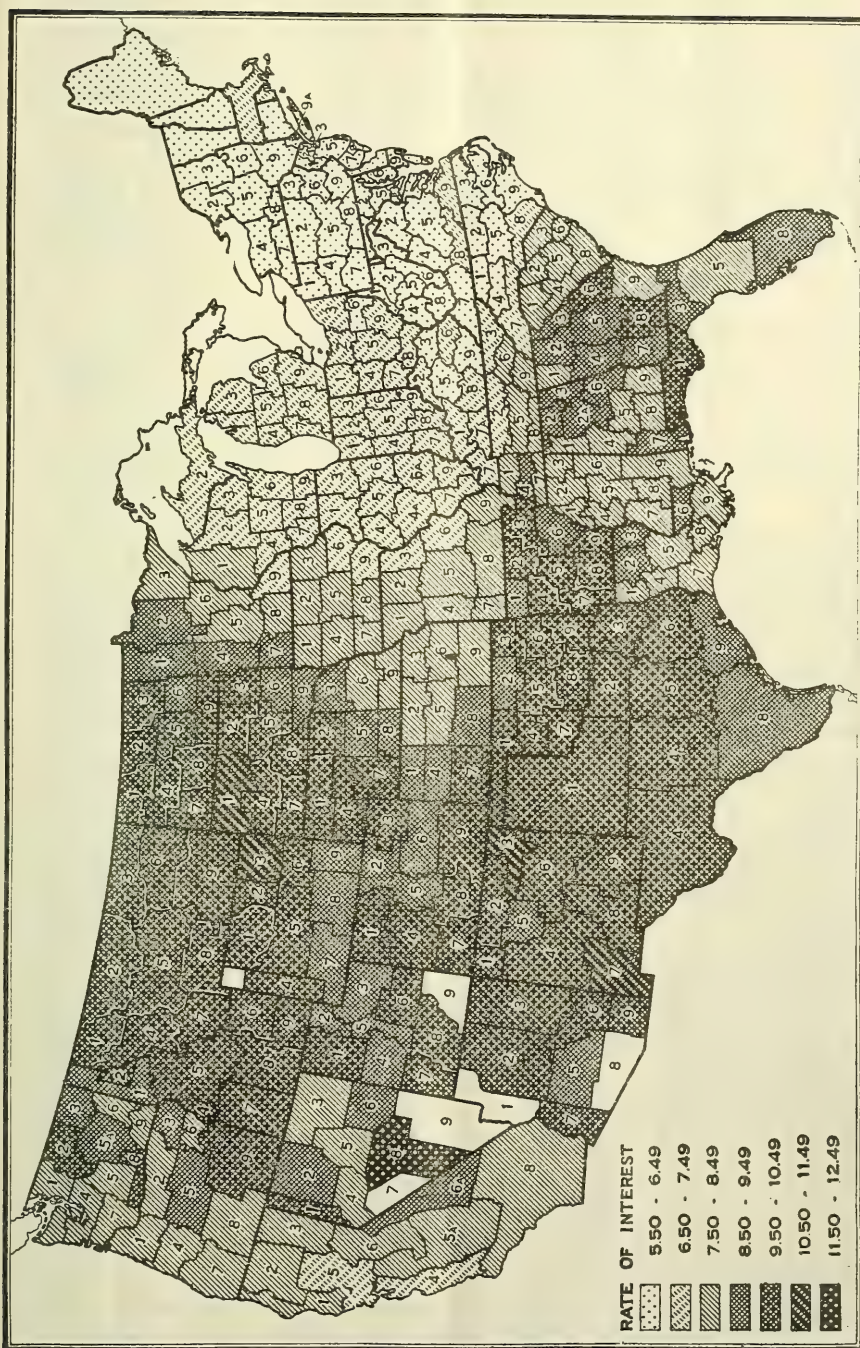


FIG. 2.—Crop estimates districts referred to in Table 2, and approximate prevailing interest rate on personal and collateral loans of \$100 or more in each such district.

The range in the prevailing rates as reported in Table 3 is also of interest. For the United States, 35.2 per cent of the banks which replied to this question reported rates varying from 7.50 to 8.49 per cent. Rates of from 5.50 to 6.49 per cent, which are shown as prevalent for New England and Middle Atlantic, disappear almost entirely in the West South Central and Mountain States, where a rate of 9.50 per cent or more was charged by three-fourths of the banks. Rates exceeding 11.50 per cent were reported by nearly 9 per cent of the banks in Georgia, by 10 per cent of those in Nevada, and by 11 per cent of those in New Mexico.

TABLE 3.—*Prevailing rates of interest on personal and collateral loans to farmers: Per cent of banks reporting the various rates, March, 1921.*¹

Geographic division and State.	5 per cent.	6 per cent.	7 per cent.	8 per cent.	9 per cent.	10 per cent.	11 per cent.	12 per cent or over.
United States..	0.0	17.1	20.0	35.2	4.9	22.1	0.1	0.6
New England.....		59.7	32.3	8.0				
Maine.....		71.4	23.8	4.8				
New Hampshire.....		100.0						
Vermont.....		96.8	3.2					
Massachusetts.....		22.1	58.4	19.5				
Rhode Island.....			100.0					
Connecticut.....		69.8	27.9	2.3				
Middle Atlantic.....	.1	99.1	.7			.1		
New York.....		98.5	1.5					
New Jersey.....		100.0						
Pennsylvania.....	.3	99.1	.3			.3		
East North Central..		16.3	67.5	15.8	.3	.1		
Ohio.....		28.6	61.9	9.5				
Indiana.....		8.3	50.5	41.2				
Illinois.....		16.2	82.1	1.5		.2		
Michigan.....		8.6	84.5	4.9	1.6	.4		
Wisconsin.....		17.7	58.9	23.1	.3			
West North Central..		1.0	9.5	54.3	8.0	26.6	.1	.5
Minnesota.....			9.8	57.1	12.0	21.1		
Iowa.....		1.8	21.4	76.8				
Missouri.....		4.0	22.2	72.0	1.1	.2		.5
North Dakota.....				4.6	8.2	87.2		
South Dakota.....				18.8	12.6	63.2	1.2	4.2
Nebraska.....			1.6	43.8	19.2	35.1		.3
Kansas.....		.2	2.2	72.6	8.5	16.5		
South Atlantic.....		39.7	2.2	43.4	3.1	8.1	.9	2.6
Delaware.....		100.0						
Maryland.....		98.4	1.6					
District of Columbia.....		50.0	50.0					
Virginia.....		88.3	5.4	6.3				
West Virginia.....		96.4	1.8	1.8				
North Carolina.....		86.8	4.7	7.5		1.0		
South Carolina.....			2.3	93.6	.6	2.9		.6
Georgia.....				62.3	6.1	19.9	3.0	8.7
Florida.....				54.0	20.0	26.0		
East South Central..		17.0	6.7	64.0	3.3	8.0		1.0
Kentucky.....		51.1	21.4	25.2	1.5	.8		
Tennessee.....		18.8	4.8	59.2	3.8	13.4		
Alabama.....			.7	77.1	5.7	13.6		2.9
Mississippi.....			1.4	93.0	2.1	2.1		1.4
West South Central..			.3	13.2	8.7	77.1	.1	.6
Arkansas.....				9.8	9.8	80.4		
Louisiana.....				77.5	8.2	14.3		
Oklahoma.....				4.4	6.2	89.4		
Texas.....			.6	12.1	10.5	75.1	.3	1.4

¹ Rates involving fractions of 1 per cent are approximated to the nearest unit.

TABLE 3.—*Prevailing rates of interest on personal and collateral loans to farmers: Per cent of banks reporting the various rates, March, 1921—Continued.*

Geographic division and State.	5 per cent.	6 per cent.	7 per cent.	8 per cent.	9 per cent.	10 per cent.	11 per cent.	12 per cent or over.
Mountain.....			.2	14.1	10.0	73.7	.3	1.7
Montana.....				3.4	2.8	93.8		
Idaho.....				16.5	11.0	72.5		
Wyoming.....				12.3	14.0	66.6	1.8	5.3
Colorado.....			.7	20.9	13.7	64.0		.7
New Mexico.....				2.9	2.9	79.9	2.9	11.4
Arizona.....				16.0	24.0	60.0		
Utah.....				30.0	17.5	50.0		2.5
Nevada.....				60.0	10.0	20.0		10.0
Pacific.....		.6	22.0	62.1	4.4	10.7		.2
Washington.....			2.2	65.7	6.7	24.7		.7
Oregon.....			6.5	74.2	4.8	14.5		
California.....		1.1	38.0	55.2	3.2	2.5		

MINIMUM BALANCE REQUIREMENTS FOR BANK LOANS TO FARMERS ON PERSONAL AND COLLATERAL SECURITY.

As a rule, when a farmer obtains a loan at a bank he leaves the proceeds on deposit subject to withdrawal by check. This practice is entirely to his advantage as well as to that of the bank, so long as he can draw on the proceeds of the loan at his convenience. Some banks, however, require that a certain portion of the loan be kept permanently on deposit so long as the loan exists. This has the effect of making the loan actually extended smaller than the face of the note on which the interest charge is based. Six per cent of the banks reported a minimum balance requirement on 16.3 per cent of their loans. The purpose of such a requirement seems to be either the procuring of a higher rate of interest or the reduction of the risk involved by means of keeping a certain percentage of the loan in the control of the bank.

As an illustration of the effect which a balance requirement has on interest cost, let it be assumed that a farmer obtains a loan at 6 per cent on which 20 per cent of the proceeds are required to be kept at the bank. The actual interest cost would then be not 6 per cent but $7\frac{1}{2}$ per cent. Similarly, a loan with the same minimum balance requirement at a rate of 8 per cent would cost the borrower 10 per cent. It seems probable that these practices have resulted from the mistake of establishing by law a maximum rate of interest which is lower than is justified by the available supply of capital in relation to demand. Under such circumstances, creditors are tempted to resort to evasions, the effects of which many debtors may not comprehend and which in many instances no doubt bring the actual cost above what it would be if the laws were so drawn as merely to prevent actual extortion without attempting to regulate the rate in a free and open market.

TABLE 4.—*Minimum balance requirements for bank loans to farmers on personal and collateral security.*

Geographic division and State.	Number of banks reporting.	Percentage which required no minimum balance.	Percentage which required minimum balance.	Average per cent required by banks reporting such requirements.
United States.....	9,629	94	6	16.3
New England.....	271	92	8	18.8
Maine.....	45	100		
New Hampshire.....	33	100		
Vermont.....	34	88	12	13.3
Massachusetts.....	97	89	11	19.5
Rhode Island.....	6	83	17	20.0
Connecticut.....	56	87	13	20.0
Middle Atlantic.....	746	94	6	15.0
New York.....	309	95	5	17.8
New Jersey.....	72	83	17	18.0
Pennsylvania.....	365	95	5	9.5
East North Central.....	2,039	97	3	15.6
Ohio.....	388	97	3	16.7
Indiana.....	399	98	2	20.0
Illinois.....	599	97	3	14.9
Michigan.....	260	98	2	12.0
Wisconsin.....	393	97	3	14.0
West North Central.....	3,081	96	4	16.0
Minnesota.....	466	97	3	16.2
Iowa.....	600	95	5	17.2
Missouri.....	471	95	5	15.8
North Dakota.....	373	98	2	12.8
South Dakota.....	265	94	6	13.4
Nebraska.....	394	95	5	16.3
Kansas.....	512	94	6	17.7
South Atlantic.....	850	88	12	17.3
Delaware.....	12	83	17	5.0
Maryland.....	65	83	17	11.3
District of Columbia.....	2	50	50	20.0
Virginia.....	118	84	16	16.1
West Virginia.....	63	95	5	10.0
North Carolina.....	107	85	15	19.6
South Carolina.....	182	90	10	13.0
Georgia.....	250	89	11	19.6
Florida.....	51	84	16	21.6
East South Central.....	637	93	7	17.4
Kentucky.....	140	90	2	15.0
Tennessee.....	205	93	7	18.6
Alabama.....	142	96	4	9.3
Mississippi.....	150	85	15	18.6
West South Central.....	837	93	7	19.0
Arkansas.....	120	95	5	21.7
Louisiana.....	51	84	16	14.0
Oklahoma.....	287	95	5	22.5
Texas.....	379	93	7	19.4
Mountain.....	593	93	7	14.9
Montana.....	180	95	5	15.0
Idaho.....	90	94	6	13.3
Wyoming.....	58	88	12	20.0
Colorado.....	156	94	6	14.6
New Mexico.....	36	92	8	10.0
Arizona.....	23	91	9	15.0
Utah.....	41	93	7	15.0
Nevada.....	9	100		
Pacific.....	575	93	7	15.7
Washington.....	141	93	7	15.8
Oregon.....	124	99	1	
California.....	310	91	9	15.7

TABLE 5.—Collection of interest in advance on personal and collateral loans to farmers: Per cent of banks collecting in advance and per cent of their farm loans on which advance collection is made.

Geographic division and State.	Number of banks reporting.	Per cent of banks reporting—		Per cent of farm loans on which advance collection was made (in case of banks reporting such collection).
		No collection in advance.	Collection in advance.	
United States.....	8,827	60	40	66.0
New England.....	225	29	71	82.4
Maine.....	38	29	71	65.8
New Hampshire.....	27	30	70	76.7
Vermont.....	30	33	67	70.6
Massachusetts.....	81	42	58	85.5
Rhode Island.....	5	-----	100	99.0
Connecticut.....	44	7	93	95.7
Middle Atlantic.....	628	21	79	76.5
New York.....	267	38	62	60.1
New Jersey.....	59	-----	100	90.7
Pennsylvania.....	302	10	90	82.9
East North Central.....	1,851	64	36	54.0
Ohio.....	361	59	41	59.6
Indiana.....	374	43	57	56.4
Illinois.....	519	69	31	60.2
Michigan.....	237	54	46	40.1
Wisconsin.....	360	90	10	27.1
West North Central.....	2,973	83	17	43.6
Minnesota.....	511	92	8	20.3
Iowa.....	566	96	4	11.9
Missouri.....	452	56	44	52.2
North Dakota.....	354	96	4	24.2
South Dakota.....	245	92	8	18.5
Nebraska.....	364	89	11	23.5
Kansas.....	481	62	38	51.1
South Atlantic.....	745	14	86	82.7
Delaware.....	11	18	82	87.8
Maryland.....	53	24	76	70.8
District of Columbia.....	2	50	50	10.0
Virginia.....	107	5	95	93.4
West Virginia.....	52	2	98	91.1
North Carolina.....	101	-----	100	97.6
South Carolina.....	165	4	96	87.6
Georgia.....	215	34	66	58.4
Florida.....	39	10	90	83.3
East South Central.....	557	24	76	75.3
Kentucky.....	124	15	85	79.3
Tennessee.....	172	5	95	85.7
Alabama.....	129	28	72	68.1
Mississippi.....	132	52	48	52.0
West South Central.....	746	33	67	64.5
Arkansas.....	113	49	51	52.2
Louisiana.....	47	6	94	72.4
Oklahoma.....	258	32	68	58.8
Texas.....	328	33	67	70.8
Mountain.....	565	85	15	48.1
Montana.....	169	91	9	20.6
Idaho.....	84	87	13	30.8
Wyoming.....	57	98	2	2.0
Colorado.....	152	87	13	50.8
New Mexico.....	32	28	72	74.3
Arizona.....	24	67	33	58.5
Utah.....	38	79	21	35.7
Nevada.....	9	100	-----	0.0
Pacific.....	537	89	11	44.5
Washington.....	134	81	19	54.1
Oregon.....	120	94	6	40.7
California.....	283	91	9	35.1

INTEREST COLLECTIONS IN ADVANCE.

A second practice which has the effect of increasing interest cost is that of collecting the interest at the time the loan is made. As indicated in Table 5, 40 per cent of the banks follow this practice on 66 per cent of their loans to farmers on personal and collateral security. This would indicate that, taking the United States as a whole, interest is collected in advance on slightly more than one-fourth of all short-time bank loans to farmers. This practice, it may be noted, is most common in the eastern and southern sections of the country, and occurs only rarely in the central or western States. Thus in the States of Rhode Island, Connecticut, New Jersey, Pennsylvania, Virginia, West Virginia, North Carolina, South Carolina, Florida, Louisiana, and Tennessee, 90 per cent or more of the banks reporting collected interest in advance on a large majority of their loans. In Nevada, on the other hand, no bank reporting on the question followed this practice. In Wyoming, only 2 per cent reported collections in advance and on only 2 per cent of their loans. In each of the States of Iowa, Minnesota, North Dakota, South Dakota, Montana, Oregon, and California less than 10 per cent of the banks followed this practice on any part of their loans. The collection of 6 per cent interest in advance makes the rate on the credit actually obtained 6.4 per cent, while the collection of 8 per cent interest in advance makes the actual rate 8.7 per cent.

NATURE OF SECURITY FOR FARMERS' PERSONAL AND COLLATERAL LOANS.

Table 6 discloses the marked prominence of purely personal security in rural short-time credit. For the country as a whole, 36 per cent of farmers' short-time loans from banks reporting on this subject had no security other than the written promise of the debtor to pay at the proper time. In Iowa 66.3 per cent of the personal and collateral loans were of this nature. In other States, loans secured by the indorsement of one or more persons are the prevailing type. In Rhode Island, 97.5 per cent of the personal and collateral loans were of this class, as were also two-thirds or more of the loans in Vermont, Connecticut, New Jersey, and Pennsylvania. Combining the figures of the first two columns, it will be observed that in the United States, 68 per cent of these loans were strictly personal or character loans. The lowest total occurs for Oklahoma, where 30 per cent of the loans rest on personal security only.

Considering the kind of collateral pledged, mortgages on live stock are of most importance, 18.3 per cent of the total personal and collateral loans to farmers in the United States being based on this form of security. In the West South Central and Mountain States mortgages on live stock are particularly common.

TABLE 6.—*Form of security given for personal and collateral bank loans to farmers.*

Geographic division and State.	Total number of banks reporting.	Per cent of loans secured by—						
		Note without indorsement.	Note with one or more indorsements.	Mortgage on live stock.	Crop lien.	Warehouse receipt.	Stocks and bonds.	Other ways.
United States..	7,590	36.0	32.0	18.3	6.2	1.4	4.2	1.9
New England.....	160	15.7	62.6	1.7	.....	.3	18.1	1.6
Maine.....	30	16.4	53.8	2.7	.....	.....	23.1	4.0
New Hampshire..	22	8.6	64.9	1.8	.....	.....	22.1	2.6
Vermont.....	25	17.8	73.9	1.7	.....	.....	6.6	.....
Massachusetts....	50	21.5	55.7	2.1	.....	.....	19.3	1.4
Rhode Island.....	4	.....	97.5	.....	.....	.....	2.5	.....
Connecticut.....	29	10.8	67.4	.2	.....	1.4	19.9	.3
Middle Atlantic.....	519	19.8	67.6	1.0	.....	.2	9.1	2.3
New York.....	185	26.0	62.3	2.2	.....	.5	7.4	1.6
New Jersey.....	63	8.9	78.0	.1	.....	.1	11.3	1.6
Pennsylvania.....	271	18.0	68.9	.3	.....	.1	9.7	3.0
East North Central..	1,498	46.8	43.9	3.3	.3	.1	4.7	.9
Ohio.....	265	43.8	46.7	1.0	.2	.....	7.5	.8
Indiana.....	321	28.8	62.1	1.8	.2	.1	6.2	.8
Illinois.....	423	52.6	40.6	2.8	.5	.1	2.7	.7
Michigan.....	197	48.5	41.0	5.6	.5	.1	3.5	.8
Wisconsin.....	292	59.8	28.1	6.5	.3	.1	4.0	1.2
West North Central..	2,713	47.6	17.3	25.0	5.7	.6	1.8	2.0
Minnesota.....	450	51.8	14.2	25.0	4.1	.3	2.3	2.3
Iowa.....	501	66.3	20.0	9.3	1.6	.4	1.6	.8
Missouri.....	412	46.3	34.7	13.0	2.0	.2	2.7	1.1
North Dakota.....	336	26.8	8.9	43.2	12.4	2.5	1.7	4.5
South Dakota.....	233	34.6	8.6	46.0	6.0	.5	2.1	2.2
Nebraska.....	345	49.2	16.6	24.6	6.4	.1	.8	2.3
Kansas.....	436	44.9	13.0	29.7	9.5	.3	1.2	1.4
South Atlantic.....	644	11.4	57.6	9.2	7.3	5.8	5.8	2.9
Delaware.....	9	15.0	80.6	1.1	.....	.....	3.3	.....
Maryland.....	51	15.0	73.5	1.3	.....	.....	9.0	1.2
District of Columbia	2	1.0	70.0	.....	.....	.....	29.0	.....
Virginia.....	87	6.5	83.1	2.0	.1	.....	7.7	.6
West Virginia.....	30	9.8	75.9	1.6	.1	.....	9.5	3.1
North Carolina.....	77	10.5	68.6	1.7	5.2	2.1	7.5	4.4
South Carolina.....	154	9.1	41.0	13.6	20.2	9.7	4.8	1.6
Georgia.....	203	12.5	50.1	14.5	4.9	10.0	3.5	4.5
Florida.....	31	27.0	40.1	13.8	6.5	1.7	6.8	4.1
East South Central..	458	15.9	45.9	14.1	10.4	4.0	6.4	3.3
Kentucky.....	90	22.5	63.6	1.6	1.1	.1	9.0	2.1
Tennessee.....	152	18.1	67.2	5.0	1.5	.8	5.8	1.6
Alabama.....	107	10.4	20.1	31.5	26.1	7.5	2.4	2.0
Mississippi.....	109	12.7	27.0	20.2	15.1	8.0	9.1	7.9
West South Central..	719	18.5	20.9	38.6	17.7	1.5	1.7	1.1
Arkansas.....	101	12.1	37.9	22.7	19.9	3.0	2.2	2.2
Louisiana.....	40	15.5	52.7	12.4	5.2	2.7	9.0	2.5
Oklahoma.....	265	17.2	12.9	49.3	18.1	.7	1.2	.6
Texas.....	313	21.9	18.0	38.1	18.3	1.6	1.1	1.0
Mountain.....	489	27.9	12.2	39.6	12.1	1.4	3.5	3.3
Montana.....	151	22.9	6.7	44.9	17.1	1.8	1.8	4.8
Idaho.....	73	45.5	11.5	20.0	13.8	3.1	4.1	2.0
Wyoming.....	45	19.0	13.1	56.7	7.0	.2	2.1	1.9
Colorado.....	134	28.9	13.3	42.5	9.5	.1	2.8	2.9
New Mexico.....	32	22.1	16.2	50.7	8.0	.8	1.6	.6
Arizona.....	18	20.3	20.8	26.5	16.5	5.4	3.8	6.7
Utah.....	30	26.4	25.2	22.7	5.9	.7	15.8	3.3
Nevada.....	6	47.3	17.2	16.0	6.7	1.7	7.8	3.3
Pacific.....	390	49.0	13.2	15.0	8.3	4.5	7.8	2.2
Washington.....	111	43.6	13.4	19.2	11.4	4.8	4.8	2.8
Oregon.....	90	53.8	13.4	16.8	5.9	4.0	3.3	2.8
California.....	189	50.0	13.1	11.8	7.5	4.5	11.6	1.5

Crop liens come next in importance, being relatively common all over the southern, central, and western part of the country, but practically unknown in States of the East. As the practice of crop insurance develops, crop liens will no doubt become more common as a form of security.

Considerable interest has been shown recently in an improved system of warehouse receipts. The fifth column of Table 6 indicates that although some loans are secured by this type of collateral, it as yet plays a minor part. As improved marketing systems are adopted for the various farm products, greater attention undoubtedly will be given to warehouse receipts. Their acceptability as security has been demonstrated particularly in certain southern States where warehouses are operated under the joint supervision of the State and Federal Governments.

The flotation and wide distribution of Government bonds during and after the war, which were bought by farmers largely on patriotic grounds, will no doubt explain the relatively large and uniform percentages of loans reported as secured by stocks and bonds. Unfortunately, the farmers as a class have not yet attained a position where they have an appreciable amount of earnings to place in investments outside of their own business.

TERM OF LOAN.

One of the most frequent complaints heard with reference to bank loans to farmers is that the term is too short to meet the needs of the producers of agricultural products, particularly those producing live stock. Table 7 presents the average maximum term of personal and collateral loans to farmers as reported by 8,008 banks. For the United States as a whole, nearly one-half of the banks reported a maximum term of 6 months or less, and most of the remaining banks reported a term ranging from 9 months to a year. The shorter maximum term prevails to a larger extent in the East, but in the geographic divisions where agriculture is considered of chief importance the longer maximum term is more common.

Table 8 presents the average term of such loans. As might be expected, the average as well as the maximum term was reported in approximate periods only. For this reason, it was not possible to tabulate the replies in groups which are mutually exclusive. For the United States, the average term falls between 3 and 6 months. Practically one-fourth of the loans run for 6 months or more. In the Eastern States, more loans are made for a term of 3 months or less, than for 6 months or more, but in the central and western sections the reverse is true.

TABLE 7.—*Maximum term of personal and collateral loans to farmers: Per cent of banks reporting various maximum terms, March, 1921.*

Geographic division and State.	Total number of banks reporting.	Demand.	One to thirty days.	One to three months.	Three to six months.	Six to nine months.	Nine to twelve months.	More than one year.
United States..	8,008	0.8	0.4	4.6	41.6	6.8	45.2	0.6
New England.....	146	17.8	.....	6.2	61.6	.....	14.4	.....
Maine.....	30	16.7	.....	.....	76.6	.....	6.7	.....
New Hampshire.....	17	29.4	.....	.....	58.8	.....	11.8	.....
Vermont.....	26	30.8	.....	3.8	50.0	.....	15.4	.....
Massachusetts.....	45	8.9	.....	8.9	53.3	.....	28.9	.....
Rhode Island.....	3	.....	.....	33.3	66.7	.....	.....	.....
Connecticut.....	25	16.0	.....	12.0	72.0	.....	.....	.....
Middle Atlantic.....	528	1.9	.2	21.4	54.9	3.2	18.2	.2
New York.....	201	1.5	.5	18.4	58.7	5.5	15.4	.....
New Jersey.....	60	1.7	.....	28.2	55.0	6.7	6.7	1.7
Pennsylvania.....	267	2.2	.....	22.1	52.1	.7	22.9	.....
East North Central..	1,669	.7	.5	4.6	48.9	3.0	41.4	.9
Ohio.....	302	2.3	.7	4.3	57.6	2.3	32.8	.....
Indiana.....	341	.....	1.5	5.9	58.3	4.7	29.6	.....
Illinois.....	482	.2	.....	4.1	42.8	2.3	50.4	.2
Michigan.....	214	.....	.....	5.1	44.9	4.2	45.3	.5
Wisconsin.....	330	1.0	.3	3.9	42.7	2.4	45.8	3.9
West North Central..	2,798	.4	.4	1.8	41.0	4.7	51.3	.4
Minnesota.....	473	.4	.2	1.3	20.3	4.9	72.5	.4
Iowa.....	542	.....	.4	1.7	38.2	3.5	56.2	.....
Missouri.....	424	.7	.9	4.0	51.4	3.1	39.4	.5
North Dakota.....	334	.6	.....	.....	4.2	5.7	88.0	1.5
South Dakota.....	237	.....	.....	.4	35.9	6.3	57.4	.....
Nebraska.....	330	.6	.3	2.7	61.5	6.1	28.5	.3
Kansas.....	458	.2	.4	2.2	71.0	4.8	21.4	.....
South Atlantic.....	666	.....	.5	6.9	30.6	16.2	45.5	.3
Delaware.....	7	.....	.....	28.6	42.8	.....	28.6	.....
Maryland.....	50	.....	.....	10.0	68.0	2.0	20.0	.....
District of Columbia	2	.....	50.0	.....	.....	.....	.....	.....
Virginia.....	96	.....	.....	11.4	56.2	4.2	27.1	1.1
West Virginia.....	42	.....	.....	2.4	88.1	.....	9.5	.....
North Carolina.....	85	.....	1.2	10.6	33.0	17.6	36.4	1.2
South Carolina.....	151	.7	.....	3.3	10.6	22.5	62.9	.....
Georgia.....	196	.....	.....	2.1	11.2	27.0	59.7	.....
Florida.....	37	.....	.....	21.6	27.0	2.7	48.7	.....
East South Central..	514	.....	.6	6.0	25.3	6.8	59.9	1.4
Kentucky.....	109	.....	.9	2.8	45.9	.9	47.7	1.8
Tennessee.....	164	.....	.....	13.4	37.2	4.3	43.9	1.2
Alabama.....	121	.....	.8	2.5	7.4	11.6	76.9	.8
Mississippi.....	120	.....	.8	2.5	8.3	10.8	75.9	1.7
West South Central..	724	.1	.6	2.1	25.4	18.6	53.1	.1
Arkansas.....	99	.....	.....	3.0	14.1	21.2	61.7	.....
Louisiana.....	42	.....	.....	4.8	11.9	19.0	61.9	2.4
Oklahoma.....	271	.....	1.1	1.5	29.2	15.9	52.3	.....
Texas.....	312	.3	.3	1.9	27.6	20.2	49.7	.....
Mountain.....	536	.2	.4	2.1	48.7	6.7	41.3	.6
Montana.....	161	.....	.6	.6	25.5	6.2	67.1	.....
Idaho.....	83	.....	1.2	2.4	41.0	10.8	44.6	.....
Wyoming.....	54	.....	.....	.....	61.1	5.6	29.6	3.7
Colorado.....	146	.....	.....	2.7	66.5	8.2	21.9	.7
New Mexico.....	29	.....	.....	3.4	65.5	.....	31.1	.....
Arizona.....	23	.....	.....	8.7	60.9	4.3	26.1	.....
Utah.....	34	2.9	.....	2.9	61.8	2.9	29.5	.....
Nevada.....	6	.....	.....	.....	33.3	.....	66.7	.....
Pacific.....	427	.9	.....	4.0	49.4	7.5	36.8	1.4
Washington.....	117	.....	.....	6.8	41.0	7.7	44.5	.....
Oregon.....	105	1.9	.....	.9	58.1	4.8	34.3	.....
California.....	205	1.0	.....	3.9	49.8	8.8	33.6	2.9

TABLE 8.—Average term of personal and collateral loans to farmers: Per cent of banks reporting various average terms, March, 1921.

Geographic division and State.	Total number of banks reporting.	Demand.	One to thirty days.	One to three months.	Three to six months.	Six to nine months.	Nine to twelve months.	More than one year.
United States....	7,627	0.1	.....	17.3	58.6	15.4	7.8	0.8
New England.....	109	.9	.....	33.1	56.0	1.8	7.3	.9
Maine.....	20	.....	.....	.....	90.0	5.0	5.0	.....
New Hampshire..	13	7.7	.....	23.1	69.2	.....	.....	.....
Vermont.....	17	.....	.....	52.9	41.2	.....	5.9	.....
Massachusetts..	34	.....	.....	41.2	38.3	.....	17.6	2.9
Rhode Island....	4	.....	.....	50.0	25.0	.....	.....	.....
Connecticut.....	21	.....	.....	38.1	61.9	.....	.....	.....
Middle Atlantic....	492	.8	.....	51.2	37.6	3.9	5.1	1.4
New York.....	195	.5	.....	48.7	42.6	4.6	2.6	1.0
New Jersey.....	55	3.6	.....	58.2	30.9	.....	7.3	.....
Pennsylvania....	242	.4	.....	51.7	35.1	4.1	6.6	2.1
East North Central..	1,589	.1	.....	20.6	67.2	6.9	4.5	.7
Ohio.....	270	.7	.....	21.9	67.8	4.1	4.4	1.1
Indiana.....	336	.....	.....	28.0	64.8	4.5	2.7	.....
Illinois.....	461	.....	.....	16.3	72.4	6.5	4.6	.2
Michigan.....	204	.....	.....	26.9	60.3	7.4	3.9	1.5
Wisconsin.....	318	.....	.....	14.2	65.7	12.3	6.6	1.2
West North Central..	2,700	.....	.1	12.4	63.0	14.7	9.2	.6
Minnesota.....	463	.....	.....	3.7	59.8	22.5	14.0	.....
Iowa.....	525	.....	.2	9.7	72.0	13.7	4.0	.4
Missouri.....	414	.....	.....	18.6	70.1	5.3	5.8	.2
North Dakota....	312	.....	.....	1.0	22.1	40.0	35.6	1.3
South Dakota....	232	.....	.....	10.4	62.5	19.8	5.6	1.7
Nebraska.....	314	.....	.....	17.2	75.8	2.9	2.5	1.6
Kansas.....	440	.....	.2	25.0	68.9	4.1	1.6	.2
South Atlantic.....	628	.....	.....	17.5	49.5	25.7	5.9	1.4
Delaware.....	8	.....	.....	50.0	25.0	12.5	12.5	.....
Maryland.....	44	.....	.....	15.9	72.7	4.6	.....	6.8
District of Columbia..	2	.....	.....	50.0	.....	.....	50.0	.....
Virginia.....	86	.....	.....	40.7	48.8	7.0	2.3	1.2
West Virginia....	41	.....	.....	7.3	65.9	2.4	12.2	12.2
North Carolina..	82	.....	.....	28.0	53.7	15.9	2.4	.....
South Carolina..	152	.....	.....	12.5	40.1	40.8	6.6	.....
Georgia.....	179	.....	.....	3.9	50.3	38.5	7.3	.....
Florida.....	34	.....	.....	32.4	38.2	20.6	8.8	.....
East South Central..	474	.....	.....	13.3	44.3	25.7	15.6	1.1
Kentucky.....	96	.....	.....	5.2	75.0	11.5	5.2	3.1
Tennessee.....	151	.....	.....	28.5	45.0	14.6	11.9	.....
Alabama.....	118	.....	.....	4.2	30.5	39.9	25.4	.....
Mississippi.....	109	.....	.....	9.2	31.2	38.5	19.3	1.8
West South Central..	716	.....	.1	9.2	48.2	34.7	7.7	.1
Arkansas.....	98	.....	.....	7.2	36.7	45.9	10.2	.....
Louisiana.....	43	.....	.....	9.3	37.2	37.2	16.3	.....
Oklahoma.....	260	.....	.4	11.6	49.6	31.9	6.5	.....
Texas.....	315	.....	.....	7.9	52.1	33.0	6.7	.3
Mountain.....	509	.....	.....	11.4	64.4	14.0	9.2	1.0
Montana.....	157	.....	.....	1.3	54.1	29.3	13.4	1.9
Idaho.....	78	.....	.....	12.8	70.5	11.6	5.1	.....
Wyoming.....	51	.....	.....	3.9	78.4	5.9	11.8	.....
Colorado.....	139	.....	.....	19.4	68.4	4.3	6.5	1.4
New Mexico.....	31	.....	.....	12.9	67.8	3.2	16.1	.....
Arizona.....	18	.....	.....	33.3	44.5	11.1	11.1	.....
Utah.....	30	.....	.....	20.0	66.7	13.3	.....	.....
Nevada.....	5	.....	.....	20.0	80.0	.....	.....	.....
Pacific.....	410	.5	.....	17.5	63.9	10.0	6.6	1.5
Washington.....	108	.....	.....	21.3	59.3	14.8	3.7	.9
Oregon.....	98	.....	.....	16.3	69.4	9.2	5.1	.....
California.....	204	1.0	.....	16.2	63.7	7.8	8.8	2.5

CONCLUSION.

For short-time or personal credit, the farmers rely mainly on commercial banks, estimated loans from this source amounting at the close of 1920 to nearly \$3,870,000,000. Data are not at hand for a satisfactory estimate of farmers' personal credit from general stores, implement dealers, and kindred sources which are relied upon for a considerable amount of credit, particularly in certain sections of the country. Bank credit has been unusually costly to the farmer during the past year and a half, but there is no doubt that merchant credit has been even more so. The interest charges of the merchant are almost invariably higher than those of the banks in the same locality and, in addition, a higher price is frequently placed on goods sold to a credit purchaser.

It would be better for all concerned if all credit were sought and obtained from specialized credit agencies and purchases made for cash. The truly progressive and constructive rural banker makes every effort to acquaint himself with the legitimate credit need of the farmers in his community and to supply this need to the extent of his ability. Similarly the progressive and constructive merchant frankly points out the advantages of purchases with cash instead of on credit. The farsighted and progressive farmer in his turn aims to establish definite banking connections, is thoroughly frank with the banker as well as with the merchant, and prompt and businesslike in his dealings with both. Small farmers and tenants particularly, who have hitherto been without banking connections and who have little security to offer, can materially improve their credit status by pooling their security and consolidating their credit demands by means of local credit associations or credit unions.³ The organization of such associations should be facilitated by the enactment of suitable State laws where such laws do not already exist.

As indicated on preceding pages, the rate nominally charged by banks is not in all cases the actual rate. In some States, the practice of requiring a minimum balance from the proceeds of a loan to be maintained at the bank, as well as that of collecting interest in advance, materially increases the rate on the amount actually made available to the borrower. Such subterfuges are believed to be contrary to the public interest, and where they are the result of unwise legal regulation of rates such regulations should be properly modified.

The rate of interest, so far as the legitimate credit market is concerned, can be lowered only by establishing a new relationship between the supply of capital and the demand for it. This can be accomplished only by thrift and saving. The wise farmer borrows not

³ See Department Circular 197, "The Credit Association as An Agency For Short-Time Rural Credit."

merely for the purpose of making a crop, but to give him a start in efficient production so as to enable him to acquire a working capital of his own. When he has accumulated all the capital he himself can profitably use, he continues to save a part of his income and at a reasonable profit to himself assists in supplying those less advanced than himself with the capital that they need. It is only where a spirit of energy and thrift prevails in a community, whether agricultural or industrial, that real progress in prosperity and well-being is made—a prosperity that is shared by all whether they are engaged in a profession, in trade, or in agriculture.

One of the greatest defects of bank loans to farmers under existing conditions is that credit is not available for such a length of time as is frequently needed by the farmer to mature his products and to market them in an orderly manner. For the production and marketing of crops, loans for a term of from 8 to 12 months are frequently needed, and the producer of live stock, as contrasted with the feeder or finisher of such stock, often needs credit for a period of from 1 to 3 years. To obtain a loan under existing conditions, farmers not infrequently are obliged to agree to repay the same at a time prior to that at which they have any expectation of being able to meet it, and to rely on the hope of being able to renew the loan when it falls due. Such a state of affairs is discouraging at the best, and often leads to serious results for the borrower. At present, as shown by Table 7, the maximum term with nearly half the banks is 6 months or less, and only in the case of a very small percentage of the banks are loans made for a year or more. Some means must be found for providing the crop and live-stock producer with credit running for such term as the nature of their business demands.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.

AT
5 CENTS PER COPY



UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1049

Contribution from the Bureau of Biological Survey,
E. W. NELSON, Chief.



Washington, D. C.

March 14, 1922

GAME AS A NATIONAL RESOURCE.

By T. S. PALMER, *Expert in Game Conservation.*

CONTENTS.

	Page.		Page.
Importance of game.....	1	Methods of increasing game re-	
Principal kinds of game in the		sources.....	25
United States.....	2	Protection.....	26
Big game:		Summer shooting.....	27
Deer.....	2	Spring shooting.....	28
Elk.....	4	Protecting females of big game.....	28
Moose.....	5	Establishing game refuges.....	29
Small game: Rabbits.....	6	Public hunting grounds.....	29
Game birds:		Game refuges.....	31
Quail.....	7	Restocking depleted areas.....	34
Waterfowl.....	7	Game birds.....	34
Value of game to the farmer.....	9	Deer.....	36
Value of game from the standpoint		Elk.....	39
of health.....	10	Game breeding.....	42
Returns from license fees.....	11	State game farms.....	42
Estimates of the value of game by		Private game farms.....	43
State officials.....	12	Cost of maintaining game.....	44
Limitations on excessive hunting.....	15	Warden service.....	44
Big game and quail.....	15	Game refuges.....	45
Bag limits.....	18	Game farms.....	47
Records of game killed.....	18	Suggestions for making a survey of	
Enumerations of game.....	23	game.....	47

IMPORTANCE OF GAME.

Game is produced in every State in the Union, but its full importance as a national resource has not been generally recognized, and the best method of insuring its preservation and increase is a problem which as yet has been only partially solved. Under normal conditions in the United States probably more than 6,000,000 persons engage in hunting during the open season. The number increases

NOTE.—This bulletin summarizes present information on some of the larger problems of game conservation. It is for the information of individuals and associations interested in game preservation and is prepared with a view to the more general gathering of data for use in making a survey of game resources.

from year to year and is now approximately 6 per cent of the total population, indicating that 1 person in every 16 hunts game of some kind.

With the information at present available only rough estimates of the value of game as a national resource are possible. By the estimating methods followed the annual value of the wild-life resources of the whole United States may be placed at several hundred million dollars.

The importance of game resources to any region is indicated by the extent to which they are advertised by transportation lines and by local interests in regions fortunate enough to possess game. The needs of sportsmen in the way of weapons, ammunition, special clothing, and other equipment form the foundation of business enterprises of considerable magnitude. The investment in shooting preserves owned by individuals and clubs runs into large figures and makes of productive value many areas otherwise of little or no use.

The objects of this bulletin are to discuss briefly the value of game as food and as an asset to the individual and to the State, to review the various methods by which estimates of such values are obtained, to point out some of the causes of present depleted conditions and some of the methods by which game resources may be preserved and increased, and to consider the expense involved in work of this kind. Many details must be omitted. All that is possible is to present a summary of present information on some of the larger questions of game conservation, with references to sources where further data may be found. It is hoped that this presentation may result in the systematic collection of statistics and data of a kind now available only in fragmentary and unsatisfactory form, and suggestions for such a survey of game resources are included.

PRINCIPAL KINDS OF GAME IN THE UNITED STATES.

The variety of North American game animals and birds hunted for sport, for recreation, or for food is large; but as some of the kinds are rare or local the number of species killed in any quantity for food is relatively small. Of these the most important are deer, rabbits, quail, and waterfowl.

BIG GAME.

DEER.

More than one-fourth of the States now have no deer hunting, either because the animals have been exterminated or because they have become so reduced in numbers that it has been necessary to close the season for several years to allow them to recuperate. (For

list of States, see p. 15; and map, fig. 1.) Statistics are available for only about one-third of the deer-hunting States, but include the more important hunting areas. Figures given for other States are necessarily estimates. The Biological Survey has published estimates for the years 1908, 1909, and 1910 of the number of deer killed in the States east of the Mississippi River, including Louisiana and Minnesota. The returns showed that in 15 States in 1908 the number was 59,878; in 1909, 57,494; and in 1910, in 17 States, 60,150. An estimate of the total number of deer killed throughout the United States in 1910 gave 75,000 to 80,000, and a similar estimate of the deer killed in 1915 showed about 75,000. The latter total, covering 36 States (all in which deer hunting was permitted), included abnormally large numbers killed in California, Connecticut, and Vermont, which were offset somewhat by a decrease due to closing the seasons in Colorado and North Dakota. If the average dressed weight of a deer is taken as 150 pounds, the total weight of 75,000 deer is 11,250,000 pounds. At 10 cents a pound this meat would be worth \$1,125,000, and at 20 cents a pound it would be worth \$2,250,000.

The region north of a line drawn along latitude 42° and Mason and Dixon's line includes 19 States, 16 of which had deer hunting in 1920 (the exceptions being Connecticut, Rhode Island, and North Dakota). Of the 29 States south of this line, Delaware, Maryland, West Virginia, and 9 States in the corn belt had no deer hunting, and Missouri had very little. Omitting from consideration the States in which hunting is practically closed (leaving 16 States with open seasons in the northern tier and 17 in the southern tier), the possible deer crop is more than twice as great in the northern tier as in the southern, the States north of the line having under normal conditions a possible kill of 60,000, whereas those to the south have less than 25,000. The only States to the south where the number is likely to exceed 5,000 are California and Texas, whereas at least 4 States to the North may exceed this limit, while in 4 of the New England States—Maine, New Hampshire, Vermont, and Massachusetts, where one deer, on the average, is obtained on each 5 square miles of territory—the kill might total 20,000, a number equal to the present possible crop of all the States to the south except Texas.

If the deer crop can be increased to 100,000 head a year, the quantity of meat would be increased to 15,000,000 pounds, which at 20 cents a pound would be worth \$3,000,000. To attain this total it will be necessary to increase the present number of deer killed each year 25 per cent. No permanent increase can be expected during the next few years in the number killed in 6 of the principal States—Maine, California, New York, Wisconsin, Minnesota, and Michigan. In fact, figures of the last few years are likely to show a decrease,

for in Maine, New York, Michigan, Minnesota, and Wisconsin serious inroads have been made in the breeding stock because until recently laws have permitted the killing of does. In New York in 1919, when the season was open on both bucks and does, probably more than one-third of the total number of deer in the State were killed. On the other hand, some increase may be expected in the States in the Northwest and in the Rocky Mountains, and possibly in some of the Southern States, but whether the total will reach 100,000 a year will depend largely on the success attending the application of modern methods of conservation, such as complete protection of does and fawns, reasonable limits on the number a hunter may kill, and prevention of "jacking," "firelighting," "hounding," killing in the water, and market hunting.

ELK.

Elk formerly occurred and were hunted in nearly every State. Of the five forms generally recognized, the common elk (*Cervus canadensis*), once widely distributed east of the Mississippi, has retired to the fastness of the Rocky Mountains; the Roosevelt elk (*Cervus roosevelti*) is confined to the mountains of northwestern Washington; the Pacific coast elk (*Cervus canadensis occidentalis*)¹ is found in limited numbers west of the Cascades and south of the Columbia River to northern California; the valley elk (*Cervus nannodes*) is restricted to one main herd in the upper San Joaquin Valley, Calif., and to a few small herds recently transferred to various parts of the State; and the Arizona elk (*Cervus merriami*) has been exterminated. At one point on its former range a flourishing herd of the Rocky Mountain elk has been established on the Sitgreaves National Forest in Arizona. Estimates made a few years ago showed a total of approximately 72,000 elk in the United States, whereas to-day it is doubtful if the number is much in excess of 52,000, of which about 25,000 are found in the Yellowstone National Park and adjoining regions.

Elk hunting has been closed in most States and is now restricted to a few counties in Idaho, Montana, and Wyoming, where the number is limited to one to each hunter.

The question of refuges is vital if elk are not to become extinct. The Yellowstone National Park forms the greatest natural refuge for these animals, but the herds, though they find abundant summer range within its boundaries, are obliged to leave the park in winter. The State of Washington has kept the season closed on elk for several years, and in the Olympic Mountains the Federal Govern-

¹ Some authorities consider *Cervus roosevelti* and *Cervus canadensis occidentalis* identical.

ment has established a National Monument which includes the breeding grounds of the species and thus aids in its protection. In California the valley elk has been protected for years both by the State law and, on the present range near Bakersfield, by the owners of the Miller & Lux ranch. From 1910 to 1920 nearly 4,000 elk were transferred from the Yellowstone Park and from Jackson Hole to a number of States in the West and in the East. Some of these herds, particularly those in Arizona, Colorado, and South Dakota, have thrived remarkably well, while others, located too near farms or cultivated lands, have done more or less injury to crops and have given rise to complaints and claims for damage.

No big game animal is easier to raise on a preserve or in semi-domestication than elk when suitably located and provided with abundant food, and no game animal will increase more readily; but large herds can not be maintained in farming communities or near settlements, nor will mountain refuges preserve the species unless adequate winter range is provided. Notwithstanding the comparatively few and simple requirements of the animals, the adjustment of elk refuges to conditions in the West has given rise to some perplexing problems which have not thus far been satisfactorily solved.

MOOSE.

In Canada, moose and caribou are the principal meat producers among game animals. In the United States there is no caribou hunting except in Alaska, but moose are still hunted in Minnesota and Maine, there having been an open season for them in Maine except from 1915 to 1918. It is worth while, therefore, to examine the conditions surrounding moose hunting somewhat in detail.

The center of moose hunting in eastern North America is probably in the State of Maine and in the Provinces of New Brunswick and Nova Scotia. In Maine, moose are confined to the northern and eastern sections, and probably not more than half the State can properly be considered moose country. In New Brunswick they are found in all the counties, and in Nova Scotia are hunted in all sections except on Cape Breton Island, where they have been protected for a number of years. This gives an area of about 16,500 square miles of moose territory in Maine, 28,000 in New Brunswick, and 18,300 in Nova Scotia, or a total of 62,800 square miles, a little less than the area of New England. In this region nearly 3,000 moose were recorded as killed in 1914, and probably at least 3,500 were actually killed that season. As each hunter is limited to a single moose, this indicates that more than 3,000 persons hunted moose, and on the average one moose was obtained on every 20 square miles.

Moose hunting on such a scale has been made possible by protection. Calves are protected throughout the area, and cows likewise have been protected, except in Nova Scotia prior to 1909. With this exception the limit has been one bull a year. The hunting season has varied in length from 3 months down to 10 days, and in 1920 it was open 10 days in Maine, $2\frac{1}{2}$ months in New Brunswick, and $1\frac{1}{2}$ months in Nova Scotia.² In 1907 Nova Scotia required that every moose killed should be reported, and about 1908 New Brunswick adopted the same requirement, so it is now possible to ascertain approximately the number killed in each Province.

SMALL GAME.

RABBITS.

Rabbits probably constitute the largest, cheapest, and most generally available supply of game in the United States. Abundant almost everywhere, shot for sport and market, and free from non-sale restrictions in many States, they form an important item of food supply. The jack rabbits of the West, which are a serious pest in some States, are destroyed in enormous numbers—sometimes as many as 10,000 in a single drive—but only a relatively small number are placed on the market and find their way to eastern States. Cottontails, however, are found in every State in the Union and during the autumn and winter are hunted almost everywhere. In 23 States, comprising all those east of the Mississippi River and north of latitude 36° , and in addition California, Louisiana, Minnesota, and South Carolina, there are close seasons and other regulations, but in the other States there is, at present, no restriction on hunting (see map, fig. 3, p. 17.)

The Conservation Commission of New York estimated that about 465,000 cottontails were killed in 1918 in New York; the Game Commission of Pennsylvania estimated that in the open season of 1919 about 2,700,000 rabbits were killed in that State; and a game survey of Virginia for 1920 shows 293,625 killed in that State. Statistics or even estimates of the numbers killed or sold in most other States are not available. Perhaps it is not too much to assume that the total number of rabbits killed annually in the United States is not less than four for each hunter, or a total of about 25,000,000. Ordinarily rabbits are sold at from 10 to 30 cents apiece, but in the autumn of 1920 they retailed for as much as 50 or even 75 cents each. At an average of only 20 cents each the value of this supply of meat would be not less than \$5,000,000 annually, but more im-

² Maine, 1905–1913, 6 weeks; 1913–14, 1 month; 1915–1918, closed; 1919–20, 10 days. New Brunswick, 1905–1920, $2\frac{1}{2}$ months. Nova Scotia, 1905–6, 3 months; 1907–1914, 2 months; 1915–1918, $2\frac{1}{2}$ months; 1919, 2 months; 1920, $1\frac{1}{2}$ months.

portant than its value is the fact that a nutritious and relatively cheap meat is thus distributed and made available to a considerable number of persons who can ill afford to pay high prices for beef, mutton, and pork.

GAME BIRDS.

QUAIL.

Every State has some species of quail, either native or introduced. Probably no game except ducks is more generally hunted, particularly the eastern species commonly known as bob-white. Quail protection has passed through several stages. Formerly abundant in most States, the birds were first hunted for food by pioneers and early settlers: later, commercialized, they were hunted and trapped for market in such enormous numbers that now they have become so reduced that their sale is prohibited almost everywhere. Even the privilege of hunting them for sport has been withdrawn in a number of States. In 1920 there was no quail shooting in 15 States—Colorado, Iowa, Maine, Michigan, Montana, Nebraska, Nevada, New York (except Long Island), North Dakota, Ohio, Oregon, South Dakota, Utah, Wisconsin, and Wyoming—because of the scarcity of the birds or the closing of the season. The only States in the northern tier which had an open season were New Hampshire, Vermont, Minnesota, Idaho, and Washington, but even in these States the birds were by no means abundant.

On account of existing restrictions as to sale, it is difficult to ascertain the market value of quail, but prices advanced considerably during the last century. In 1810, Audubon³ records that quail sold for 12 cents a dozen, and by 1830 the price had increased to 50 cents a dozen. In the season of 1917, two years before Congress prohibited their sale entirely in the District of Columbia, they retailed in the markets of Washington, D. C., at \$9 a dozen. Enormous numbers of quail were formerly sold in some of the larger cities, notably San Francisco, where in 1891 it was reported that about 100,000 were sold each year in the market.⁴ This was about 10 years before the sale of quail was prohibited in California. The sale of native quail is now prohibited throughout the United States except in a few counties of North Carolina.

WATERFOWL.

Enormous numbers of waterfowl are killed in the United States every year during autumn and winter. Formerly they were sold in large quantities in certain markets, notably Boston, New York, Phila-

³ Ornith. Biog., vol. 1, p. 392, 1831.

⁴ Judd, S. D. (quoting C. P. Streater), The bobwhite and other quail of the United States in their economic relations: Bull. 21, Biol. Survey, U. S. Dept. Agr., p. 48, 1905.

delphia, Baltimore, New Orleans, St. Louis, Chicago, and San Francisco, but with the progressive adoption of nonsale laws the legal traffic has been greatly restricted until it has now disappeared. With the passage of the Federal migratory-bird law in 1913 and the prohibition of spring shooting, and with seasons shortened to not more than three and a half months in any one State, the number of birds killed has been still further reduced. With the approval on July 3, 1918, of the migratory-bird treaty act, the sale of all migratory game birds was forbidden throughout the United States and Alaska. Notwithstanding all these restrictions several million waterfowl are still shot every year, and these birds furnish an important source of food in nearly every State. In considering the number of birds which have been reported as shot or shipped to market at various times, it is necessary to bear in mind the factors above mentioned and the changes which have been due to the legislation of recent years.

In certain favorable sections waterfowl are again congregating in considerable numbers where formerly the market hunter was accustomed to ply his trade almost without limit. On the Atlantic coast, ducking grounds have made famous the areas on the south side of Long Island, New York; at Barnegat Bay, New Jersey; at the head of Chesapeake Bay, Maryland; and on Currituck Sound, North Carolina. In the Mississippi Valley duck-shooting resorts are almost equally famous in Vermilion Parish and in the delta of the Mississippi, Louisiana; at Lake Surprise, Texas; in the Sunken Lands of Arkansas; at Reelfoot Lake, Tennessee; on the Illinois River; on the Sandusky marshes in Ohio; on Lake St. Clair and Saginaw Bay, Michigan; in the lake region of Wisconsin; and in southwestern Minnesota. Farther west, the Platte River, Nebraska; the Arkansas bottoms, Kansas; Bear River, Utah; Klamath Lake, Oregon; and the marshes of the Sacramento River, Suisun Bay, Los Banos, and Firebaugh, and certain localities in Orange County and in the Imperial Valley, California, are celebrated ducking grounds. One of the greatest centers for wild fowl in the country is in the vicinity of Great Salt Lake and on the marshes of Bear River, Utah. During the prevalence there of the so-called duck disease, between the years 1910 and 1916, it was estimated that more than 1,000,000 birds perished—an indication of the enormous numbers of birds which frequent these marshes in autumn.

The only system thus far devised of recording accurately or even of estimating the number of ducks killed is that of Minnesota, based on the reports of licensed hunters. In other States all that is possible is to refer to estimates which have been made of the number of birds at certain localities or of the numbers which have been

shipped to market in some years. The reports of the California Fish and Game Commission estimate that in 1911 approximately 1,000,000 ducks were killed in that State;⁵ and later (referring also to 1911) the statement was made that "during the season three years ago there were fully 250,000 wild ducks brought into the San Francisco market for sale."⁶ Estimated at the very moderate price of 50 cents each, the value of the ducks offered for sale in the city of San Francisco was \$125,000, while the value of the total number killed the same season in the State would be four times as much, or \$500,000. A more accurate estimate has recently been made in Minnesota, which reports the number of ducks killed in 1919 as 1,804,900, and in 1920 as 1,414,889 (see p. 20). Although there is at hand no definite information as to the number of waterfowl killed in many States, yet enough information is available to warrant the statement that in the entire United States the food value of the waterfowl taken must amount annually to several millions of dollars.

VALUE OF GAME TO THE FARMER.

The game on the farm is of value to the owner or tenant in several ways. Nearly every farm produces some game which may be hunted in open season, as rabbits, quail, squirrels, or other species, and this has a certain food or recreational value. Upland game birds are often of more use as destroyers of weed seeds or noxious insects than they are as food, but this phase of their economic value has been fully discussed in other publications.

Under favorable conditions the game on the farm may be greatly increased and even produced artificially, though as yet game farming has made only a beginning in the United States. Pheasants and pheasant eggs have been distributed in certain States and in some cases the persons receiving them have been successful in rearing the birds, but comparatively little concerted effort has been made by farmers to raise any large number of pheasants, either in cooperation with game departments or for supplying the market. Pheasants, wild turkeys, mallard ducks, black mallards, and wood ducks can be reared on farms, and, commanding higher prices than poultry, might be made even more profitable.⁷

Another method of utilizing the game on the farm and of making it render a direct return is to sell or lease the shooting rights. Farms are very generally posted, but owners and tenants do not as a rule attempt to obtain a direct return by leasing the hunting privileges. How valuable these may be under favorable circumstances is shown

⁵ Twenty-second Bien. Rept., for 1912, p. 22.

⁶ Twenty-third Bien. Rept., for 1914, p. 15.

⁷ Directions for raising wild fowl in captivity will be furnished on application to the Biological Survey, U. S. Department of Agriculture.

by the experience of one of the counties in North Carolina, where a few years ago on most of the farms hunting rights for quail shooting were systematically leased; in 1904 probably two-thirds of all the real-estate taxes outside the towns were paid by receipts from hunting privileges on lands leased for this purpose. In short, the quail crop was made to pay most of the taxes on the farms. The hunting privileges on a number of adjoining farms comprising an area of several hundred or a thousand acres are usually acquired by a single lessee or club, the basis of compensation being a definite rental by the acre for a term of years, with the privilege of renewal. This rental may be based on the tax rate or double this rate.

In sections where it is not feasible to lease lands on a cooperative basis or in sufficient acreage for club preserves, individual landowners who have quail or other birds on their holdings may still obtain a substantial income. By allowing sportsmen the privilege of hunting on their property and in addition by furnishing them teams, hunting dogs, and the assistance of boys for locating the game, and by providing accommodations for sportsmen from a distance, the owners will obtain a direct and very substantial return on any effort expended in increasing the game and preventing it from being killed off before the season opens.

VALUE OF GAME FROM THE STANDPOINT OF HEALTH.

In a book entitled "Our National Recreation Parks," Dr. Nicholas Senn lays special stress on the value of recreation as a restorer of health.⁸

The man who toils with his brain in the bank, the pulpit, the court room, the library, the great mercantile establishments, and last, but not least, at the bedside of the sick or in the operating room, is the one above all others in need of an occasional rest, change of mental activity and surroundings. Men who ignore nature's warnings and appeals for rest, sooner or later are made to pay dearly for their neglect, and only too often mend their ways when it is too late. Brain toil means the prolonged strenuous application of the neurons which preside over functions required in the discharge of professional duties or business transactions. If these functions are overtaxed, brain fatigue is the result. * * *

There is no country in the world that has as many imprudent brain workers as the United States. The unbridled ambition for fame, influence, and wealth leads to a strenuous life which has shortened the lives and curtailed the usefulness of thousands of our best professional and business men annually, and there are no indications pointing to an abatement of the intense struggle for supremacy in all walks of life. Fortunately, there is no country that can equal our own in the number and attractiveness of places of genuine recreation for those who are in search of mental repose. * * * One of the most desirable places for this class of patients is unquestionably the Yellowstone Park. * * *

⁸ Senn, Nicholas, Our national recreation parks, pp. 13-16, 71, Chicago, 1904.

One of the principal motives for the establishment of the Yellowstone National Park was to secure an advantageous place for the protection and perpetuation of our noble game. * * * This large tract of land is one great natural pasture well supplied with the purest water and ample cover for the game in the virgin forest and inaccessible canyons and mountain peaks. It is, in other words, an ideal natural game preserve.

Thus does one of the most eminent members of the medical profession refer to the largest of the national parks, created in part as a game refuge, and recommend persons in search of recreation or relaxation to seek health and strength amid its game and scenery.

Quail shooting, duck hunting, and the pursuit of big game all have their devotees, who, in their favorite sport, find health, relaxation, and inspiration in an outing in the woods or on the water. The lists of upland-game and duck-shooting clubs and the records of non-resident hunting licenses contain the names of statesmen, prominent bankers, business men, and captains of industry, who in this form of diversion find health and strength sufficient to warrant large expenditures of capital. The very fact that busy men of affairs are identified with various projects which afford opportunities for hunting game or prospects of increasing it shows that business men find in the pursuit of game a satisfactory return in health as well as in pleasure or relaxation.

RETURNS FROM LICENSE FEES.

The hunting-license fees now required in most of the States constitute a comparatively modern source of income, dating back only to 1895. Since that year, when the hunting-license system was in force in only a few States, it has been greatly extended, until now every State requires nonresidents to obtain licenses, and all but three—Delaware, Mississippi, and North Carolina—make similar requirements of residents. Licenses are issued not only for hunting game, but also for shipping, for breeding, and in some States for selling game. Tags are also supplied for marking each piece of game which is allowed to be sold. Where the tagging system is in operation considerable amounts may be collected, even though, as in New York, the tagging is limited to certain foreign species or to game raised in captivity.

Owing to the fact that a few States have not yet required licenses from residents, that most States allow persons to hunt on their own lands without licenses, and that some States combine hunting and fishing licenses, the license returns do not afford an accurate index of the number of hunters. Moreover, licenses are issued in such different ways and the cost of collecting data varies so much that it is almost impossible to obtain accurate figures showing the actual receipts from this source. Under these circumstances it is prac-

ticable only to estimate the total receipts, using as a basis such figures as are available for a normal year.

It was estimated prior to the war that under ordinary conditions the number of persons hunting in the United States was approximately 5,000,000. Granting that 10 per cent of this number were nonresidents, persons exempt from license requirements, and persons hunting without licenses, there were 4,500,000 hunters who should obtain resident licenses. At \$1 each the gross receipts from this source would amount to \$4,500,000. Returns from 17 States in 1914 and figures from 17 other States for a normal year prior to the war showed that about 15,400 licenses were issued to nonresidents. Of the other 14 States very few issue many nonresident licenses, so 20,000 is a conservative estimate of the number of nonresident licenses issued in an average year. The fees for these licenses varied from \$5 to \$50, but most of them ranged from \$10 to \$25. If the average fee is considered to be \$15, the average gross receipts from nonresidents would be \$300,000. The total receipts from licenses should therefore amount to about \$4,800,000 per annum. Costs of collection, defective laws, and other circumstances tend to reduce this figure considerably, and it is probable that a much smaller amount is actually collected and made available for game protection. Nevertheless, the aggregate for all States is a very large sum.

The returns collected from all the States which issue resident licenses—namely, all except Delaware, Mississippi, and North Carolina (and Florida, from which figures are not available)—showed a total of 3,570,925 resident licenses, 20,221 nonresident, and 545 alien licenses issued in 1919. These figures, however, are somewhat too high, because of the fact that several of the States issue a combined hunting and fishing license and it is impracticable to separate the fishing from the hunting licenses. In some States receipts are sufficient to bear not only the expenses of game propagation but also the cost of maintaining fish hatcheries, and in a few instances large sums collected from hunting licenses, ostensibly for game protection, have been diverted to other purposes by the legislatures.

ESTIMATES OF THE VALUE OF GAME BY STATE OFFICIALS.

Several States have made estimates from time to time of the value of fish and game within their borders. Under present methods these are necessarily mere approximations and not compiled on a uniform plan. Some include game, others game and fish, and still others tourist traffic.

The fish and game of Idaho have been estimated to be worth \$1,000,000 per annum. The Conservation Commission of Louisiana estimates the number of waterfowl killed in a single season at 371,654, a total which includes many of the smaller species, but the value

of which may be estimated at from \$150,000 to \$250,000. Michigan places the annual food value of its game animals, birds, and fish at \$500,000 and the value of the insectivorous birds at \$10,000,000. New York has estimated the value of game captured in 1918 at \$3,239,277, representing a total value of \$53,000,000. Oregon, in 1914, estimated the value of its game at \$5,000,000. Vermont values its fish and game at \$500,000 per annum, "equivalent to a dividend at the rate of 4 per cent on \$12,500,000."

The following extracts from the reports of these States show the manner in which the estimates were made:

Idaho.—The fish and game warden of Idaho stated in his report for 1913-14 (pp. 8-9) as follows:

Our fish and game have a large food value. During 1914 there were killed approximately 5,000 deer and the value of the meat is at least 20 cents per pound, whether eaten in camp or on our tables. These deer are worth \$20 each. Two hundred and fifty elk were killed, worth at least \$80 each. One hundred mountain sheep and goats were killed, worth \$10 each. The above figures are food values only; the hides and heads mounted as trophies have a value of many thousands of dollars. * * *

When we consider the food value of the fish and game taken from the whole State and in addition the value of the hides and heads of our large game animals, and the number of fur-bearing animals that are taken, a low estimate of these resources is \$1,000,000 per year. The value to health and happiness from a recreation standpoint is incalculable.

Louisiana.—The Conservation Commission of Louisiana in the report for 1912-1914 included a statistical report (p. 60) of Inspector L. Alberti, showing the combined amount of game received in the markets and taken by sportsmen during the preceding hunting season, based on actual inspection and on market receipts, with an estimated addition for the game killed by sportsmen. The report is for the season 1913-14, from October to February, on mallards, pintails, wood ducks, ringnecks, gray ducks, canvasbacks, redheads, spoonbills, teal, dos gris or bluebills, poule d'eau, snipe, and geese, with a total estimate of 371,654.

Michigan.—The Michigan State game, fish, and forestry warden estimated in his report for 1913-14 (p. 6) that the annual food value of the game animals, birds, and fishes taken in the State was \$500,000, and the value to the farmer of insectivorous and seed-eating birds was \$10,000,000.

New York.—New York has probably made the most comprehensive estimate of the value of its game resources, based on returns for the year 1918.⁹

In spite of the incompleteness of the returns, it is significant that the total amount of game taken by 208,946 licensed hunters was 1,526,960, which was an average of more than 7 animals or birds for each hunter. When it is con-

⁹ Carpenter, W. S., New York's annual game dividend: The Conservationist, Albany, N. Y., vol. 4, no. 2, pp. 19-22, February, 1921.

sidered that many of the licensees did not hunt at all, or were unsuccessful, or failed to report, the actual average of the successful hunter is seen to be very much higher. At the valuations given in the table, which are based upon current market prices for game or fur legally salable, and upon conservative estimates for all other species, this game was worth a total of \$3,239,277. This value, however, was simply the annual dividend, and not the value of the State's capital stock of wild life. If we consider that it was a dividend on the basis of 6 per cent, then the actual capital value of the State's stock of game and fur-bearing animals, on the basis of the 1918 reports of game killed, which are themselves low, is \$53,987,950. * * *

* * * One of the most important of the conclusions based upon this investigation in economic biology can thus be stated as follows:

The game and fur-bearing animals of New York State, if capitalized, are worth not less than \$53,000,000; they return an annual dividend of more than \$3,200,000; and they cost the State for their protection and increase the nominal sum of \$182,000. This cost of protection and increase is thus less than 6 per cent of the annual dividend.

Oregon.—Mr. W. L. Finley, in the report for 1914 of the Oregon Fish and Game Commission, made the following estimate:

The game of our State is worth approximately \$800,000 annually from a food standpoint. In the neighborhood of 9,000 deer, 150,000 ducks, and 45,000 Chinese pheasants are killed annually. When we also consider the numbers of grouse, quail, geese, shorebirds, and other game that are killed, when we estimate that this meat is worth from 12 to 16 cents per pound, whether on the table of the farmer, the mountaineer, or the merchant, it means a big income to our people.

* * * A large amount of money is derived annually from the hunting and trapping of our fur-bearing animals. This is a crop that is worth \$100,000 annually to our State. A large part of the revenue derived comes directly to the homesteader and the settler who needs it to develop his property. * * * From an economic and business standpoint, the game and other wild creatures of the State are worth \$5,000,000 annually to us. This is not placing a high estimate on these resources.

Vermont.—The following estimate of the fish and game commissioner of Vermont is contained in the biennial report for 1913-14, pages 3-4 and 101:

It will be acknowledged that whenever one brings to the table a mess of fish, regardless of how obtained, it has a market value. The same holds true in reference to any form of wild game, which is a luxurious substitute for meat from the butcher. When a member of the family fishes or hunts, has it occurred to the reader to figure up at market prices what he, while indulging in his favorite recreation, contributes to the luxury of the table? * * * On this basis an attempt has been made to figure up the value of all fish and game annually taken in Vermont.

The sum total, conservatively estimated at the lowest market value, makes a grand total of over \$502,000, which, at the savings-bank rate of 4 per cent, is an annual dividend on \$12,500,000. In making this estimate the value of insectivorous birds, without the aid of which authorities assert that agriculture would be impossible, has not been taken into consideration. * * * The figures do not include the returns from private preserves in the form of artificial ponds and deer parks. * * * Most of these preserves make unproductive land valuable and indirectly raise the value of adjacent property. * * *

It is safe to say that 20,000 ducks are annually killed in Vermont. While there is no lawful market for them, domesticated mallards in the New York market are worth per pair \$3 and up, but to be conservative these birds are figured at \$2 per pair, making the value of the season's bag \$20,000, or an annual dividend at 4 per cent on \$500,000.

LIMITATIONS ON EXCESSIVE HUNTING.

BIG GAME AND QUAIL.

The results of excessive hunting, and particularly hunting for market, are now beginning to be felt in several sections of the country which have been settled for a long time or in which agriculture has

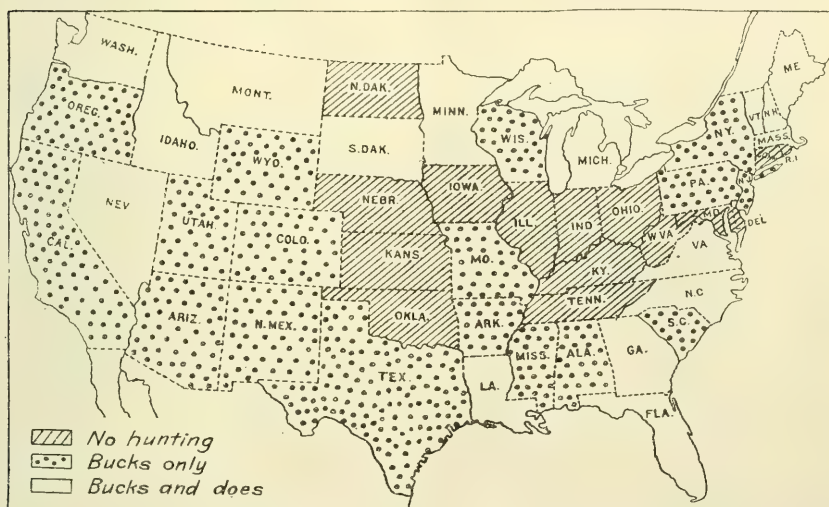


FIG. 1.—Deer hunting in the United States in 1920. In 15 States (shaded area) hunting was prohibited; in the 33 States which permitted hunting, 17 protected does (dotted area).

been highly developed. This is most apparent in the case of big game and quail, the hunting of which is not at present possible in a number of States. Fifteen States were closed to deer hunting in 1920, as follows: Connecticut, Rhode Island, Delaware, Maryland, and West Virginia in the East; and Ohio, Indiana, Kentucky, Tennessee, Illinois, Iowa, Nebraska, Kansas, Oklahoma, and North Dakota in the Middle West. In Delaware, Ohio, and Indiana deer have been exterminated for some years; in Illinois, Iowa, Kentucky, and Maryland they are nearly gone; in Connecticut they were abundant several years ago, but under a law enacted in 1915, allowing the use of shot-guns in killing deer injuring crops, several thousand were destroyed and the species greatly reduced in numbers. Of the 33 States which were open does were protected in 17, while bucks and does both could be killed in 16. (See fig. 1.)

In 1921, owing to the opening of the season in North Dakota and the protection of does in Michigan, Montana, Nevada, North Dakota, South Dakota, Vermont, and the greater part of Washington, these figures are changed as follows: No deer hunting in 14 States; does protected in 23 States; hunting bucks and does permitted in 11 States.

Fifteen States—Maine, New York (except Long Island), Ohio, Michigan, Wisconsin, Iowa, Nebraska, North Dakota, South Dakota, Montana, Wyoming, Colorado, Utah, Nevada, and Oregon (except a few counties)—during 1920 were closed to quail hunting also. (See fig. 2.) This is partly due to the great reduction in the number of birds, and partly to the fact that in the Northern States quail are not present in sufficient numbers to permit them to be hunted. The

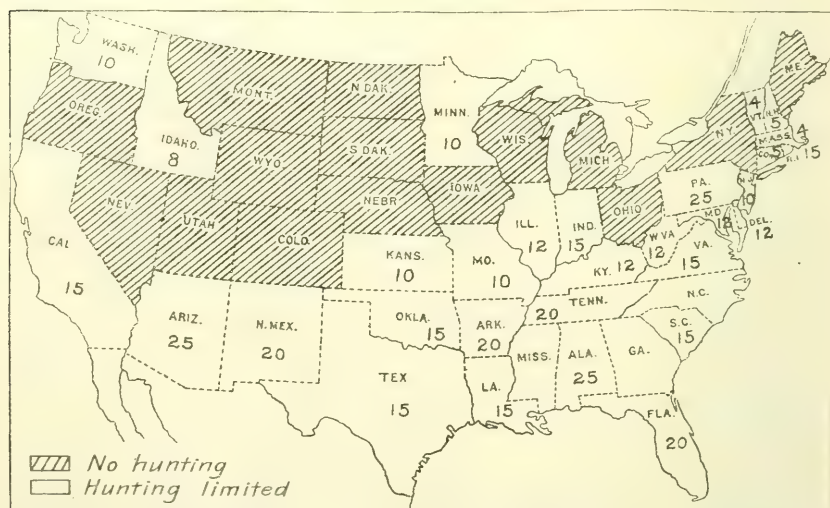


FIG. 2.—Quail hunting in 1920. The shaded portion shows the area in which hunting was prohibited. In the 33 States with open seasons, the numbers indicate the daily bag limits.

open seasons on quail in 1920 in the 33 other States varied in length from 10 days to 4 months. The daily bag limit on quail varied from 4 to 25. Fifteen States had a bag limit of 12 or less and 15 States of 15 to 25. Georgia, Mississippi, and North Carolina apparently had no State limits. In Tennessee the limit of 20 included birds and small game of all kinds.

It is not surprising that States like Maine, Michigan, Wisconsin, North Dakota, Montana, and Wyoming, which are for the most part outside the normal range of quail and in which the birds are likely to be killed off during severe winters, should not be able to obtain sufficient stock to allow general hunting, but it is remarkable that States like Iowa, Nebraska, and Ohio, which formerly were in the

center of abundance of these birds, no longer afford quail hunting. Kansas was the pioneer State in attempting to curtail traffic in game birds by prohibiting export of quail in 1876. Iowa, in 1878, attempted to restrict excessive killing by establishing a daily bag limit. The Kansas law, however, did not remain in force very long. In the nineties southern Kansas was the center of the shipment of quail for propagation, and thousands of birds were shipped from the vicinity of Wichita to various States east and west, and also to foreign countries. In 1903 the State found it necessary to close the season on quail in 19 counties; in 1905 to extend the protection three years longer in 14 of these counties; and in 1913 to give quail protection in all the counties for a period of five years. Following this

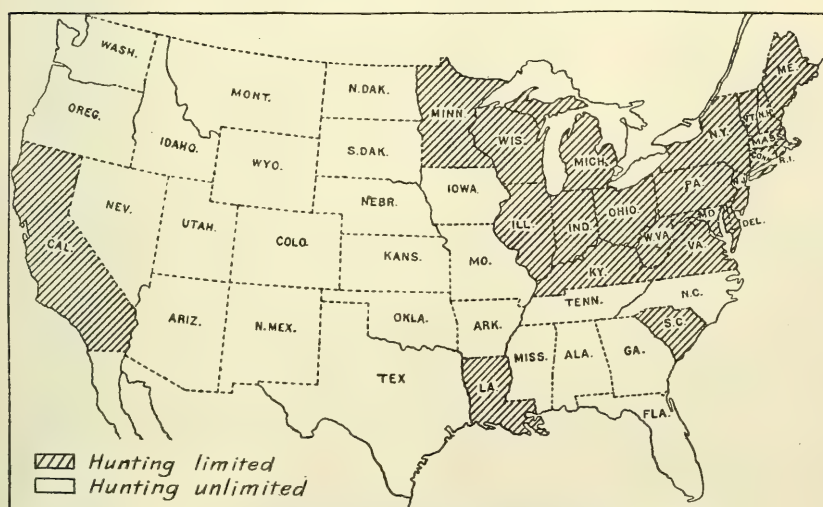


FIG. 3.—Rabbit hunting in 1920. In 23 States, chiefly in the East (shaded area), short open seasons were provided. In the remainder of the country hunting was unlimited.

example, Idaho, Iowa, and Ohio in 1917 enacted laws protecting quail throughout the year.

That deer hunting should no longer be possible in the great agricultural States in the Middle West is perhaps not surprising, but when quail shooting also is eliminated, conditions become serious for the sportsman. Three States in this section—Ohio, Iowa, and Nebraska—now have neither deer hunting nor quail shooting. In Ohio there are possibly 265,000 sportsmen, in Iowa about 105,000, in Nebraska about 65,000. Nearly 435,000 sportsmen of these three States are deprived of any big-game hunting or quail shooting unless they go elsewhere, and are forced to confine their hunting mainly to rabbits (see fig. 3) and waterfowl.

BAG LIMITS.

Daily and seasonal bag limits are established primarily to restrict the amount of game which an individual may legally kill under the most favorable circumstances. While the object of such restriction is to prevent undue destruction when game is abundant, it is not often realized how liberal these limits are in the case of certain kinds of game. In many States a resident is limited to one deer a season and the fee for a license to hunt this deer is usually \$1. Unless the deer is a small doe or a fawn of the year (the killing of which in some States is prohibited), it will dress at least 100 pounds, and for his \$1 license the hunter has authority to secure at least 100 pounds of the best wild meat. Under the same license, or in a few States under a similar bird license costing \$1, the hunter is allowed to kill a certain number of game birds. The limit for ducks is ordinarily 25 birds a day, and with fair success in hunting such of the larger ducks as mallards, black mallards, canvas-backs, or broadbills, in three or four days a hunter can obtain 100 pounds of birds, or the equivalent in weight of a season's limit of big game, while if he succeeds in getting limit bags he may secure this amount in even less time. As only a few States have placed limits on the number of rabbits which may be killed in one day, a fair amount of fresh meat can be obtained by hunting rabbits under a \$1 license, provided advantage is taken of favorable weather during the open season. In short, the quantity of wild meat, stated in pounds, which a hunter can reasonably expect to obtain under favorable circumstances and at a nominal cost so far as the State license is concerned, is very considerable.

RECORDS OF GAME KILLED.

It is rather remarkable that thus far so little progress has been made in such a fundamental subject as making an enumeration of the game or even in collecting estimates of the game annually killed. Statistics are indispensable, for without a knowledge of the quantity of game killed each year it is impossible to tell except in the most general way whether the stock is increasing or decreasing. Lack of data of this kind may perhaps be explained by the fact that until recently it was impossible to tell how many hunters there were, but since the adoption of the license system it has been possible to approximate the number of persons hunting and also to provide the means of collecting much needed information concerning the effect of hunting on the game.

Several States have undertaken to ascertain the amount of game actually killed, but very few have made more than a beginning, and

the methods of collecting such information vary as widely as the methods for determining the value of game resources.

Two States—Maine and New York—for several years kept records of the big game transported by rail: Maine, by checking shipments at Bangor and Portland since 1894, and New York, by enlisting the aid of the transportation companies which bring deer from the Adirondacks. These returns, of course, do not include the large numbers of animals consumed on the ground and never brought out of the woods. During the 20 years from 1894 to 1913, 3,434 moose and 65,305 deer were transported by rail in Maine. This source of information is less valuable than formerly, since it is now possible for private individuals to transport large numbers of deer in automobiles.

Vermont is a pioneer in recording the total number of deer actually killed, having made annual counts ever since the opening of the deer season in 1897 (see p. 38). This is probably one of the most accurate records in the country and is made by collecting data from wardens, postmasters, and from hunters themselves, not only as to numbers but as to the weights of the heavier animals.

Massachusetts has for 11 years recorded the number of deer, and since 1914 the number of pheasants killed.

Number of deer and pheasants killed in Massachusetts during the open seasons since 1910.¹

Year.	Deer.	Pheasants.	Year.	Deer.	Pheasants.
1910.....	1,382	.....	1917.....	1,017	2,772
1911.....	1,268	.....	1918.....	832	1,923
1912.....	1,231	.....	1919.....	833	2,506
1913.....	1,587	.....	1920.....	1,466	1,977
1914.....	1,312	8,943	Total.....	13,081	27,095
1915.....	1,102	5,841			
1916.....	1,051	3,133			

¹ Ann. Rept. Div. Fish and Game, Mass., 1920 pp. 40-46.

New Jersey (see p. 37) annually records the number of deer killed during the four or five days of the open season, and Minnesota and Wisconsin recorded the number killed during 1919-20. The Fish and Game Commission of California has published in some detail the figures regarding the number of deer annually killed since 1911, and has estimated on the basis of shipments received at San Francisco and other points the number of ducks killed during the open season in 1911. In Oregon, also, the commission has published some figures regarding the number of deer killed.

For most of the Western States the Forest Service has for several years collected figures as to the numbers of big game killed on the various national forests, and as these reservations include most of

the big-game areas, the statistics thus obtained are the best available for the Rocky Mountain States.

About 1910 Louisiana inaugurated an elaborate system of collecting figures from local wardens as to the number of each kind of game killed in their districts, but these figures were never published in detail and the totals were so large as to indicate that they were over-estimates in some cases. Pennsylvania published the following comprehensive statement of the total amount of game killed in the State in 1919:

Game killed in Pennsylvania, season of 1919.

[Individual and total weights estimated.]

Kind.	Number.	Individual weight.	Total weight.
		<i>Pounds.</i>	<i>Pounds.</i>
Male deer (legal) ¹	2,913	130	378,690
Bear.....	472	200	94,400
Rabbits.....	2,719,879	2	5,439,758
Squirrels.....	439,106	1	439,106
Raccoons.....	34,036	8	272,288
Wild turkeys.....	5,181	12½	64,762
Ruffed grouse.....	287,001	1½	430,501
Ring-neck pheasants.....	15,658	3	46,974
Virginia quail.....	46,319	3	17,369
Hungarian partridges.....	575	3	359
Woodcock.....	27,769	2	10,413
Wild waterfowl.....	28,714	2	57,428
Total.....			² 7,252,048

¹ There were also 119 male fawns and 207 does illegally killed during the season.

² Not including 23,786 shorebirds of various kinds nor 175,000 blackbirds killed.

Minnesota in 1919 and 1920 required holders of hunting licenses to make written reports to the commission within 30 days after the expiration of the licenses, showing the kind and the number of birds or animals taken thereunder. These returns have brought together some interesting figures, which are summarized as follows:

Game killed in Minnesota, 1919 and 1920.¹

Kind of game.	1919	1920	Kind of game.	1919	1920
Deer:			Other birds:		
Bucks.....	8,877	9,612	Coots.....	290,500	123,889
Does.....	5,183	5,028	Rails.....	1,500	1,239
Fawns, male.....	2,756	2,520	Gallinules.....	500	349
Fawns, female.....	1,470	1,412	Jacksnipe.....	20,000	25,367
Total deer.....	18,286	18,572	Yellowlegs.....	3,500	1,918
Ducks, 17 species.....	1,804,900	1,414,889	Quail.....	6,100	9,522
Geese, 4 species.....	2,350	1,880	Ruffed grouse.....		501,525
			Doves.....		3,413
			Total birds.....	2,129,350	2,083,991

¹ Condensed from paper by Carlos Avery, Minnesota's game census: Fins, Feathers, and Fur, No. 25, pp. 9-11, March, 1921.

Virginia is the most recent State to undertake a survey of its game, and through its department of game and inland fisheries has pub-

lished a report based on data obtained from game wardens and special observers showing in detail the amount and value of game killed in each county during the season of 1920. In most cases the returns are marked so as to show whether the game is increasing or decreasing. A careful study of the figures brings out several interesting facts, as, for example, the section in which certain kinds of game are most abundant. In the case of deer more than 90 per cent were killed in the southeastern part of the State, while nearly 80 per cent of the bears were obtained in Nansemond and Rockingham Counties. Following are the totals for each kind of game killed:

Game killed in Virginia in 1920.

Kind of game.	Number.	Value.	Kind of game.	Number.	Value.
Quail.....	166,570	\$83,285.00	Rabbits.....	293,625	\$146,812.50
Pheasants.....	5,175	6,468.75	Squirrels.....	108,535	21,707.00
Wild turkeys.....	4,122	12,366.00	Raccoons.....	15,611	46,833.00
Doves.....	8,410	2,102.50	Opossums.....	43,436	43,436.00
Woodcock.....	3,105	1,552.50	Muskrats.....	70,430	70,430.00
Deer.....	691	17,275.00			
Bears.....	117	3,510.00	Total.....		455,778.25

The most comprehensive work in connection with game enumerations has been done by the Conservation Commission of New York. In the winters of 1915 and 1916, and subsequently, when the deer were yarded, every game protector was required to report on the number seen in his territory, based on observations on the deer in the yards, their tracks, and such other data as were available. Monthly reports were required at other seasons, and as a result of the investigation, extending over several years, the deer population of the State in 1919 was found to be approximately 50,000. Other investigations relative to grouse, woodcock, and waterfowl also were made. During 1919 applicants for hunting licenses were required to file with their applications a statement of the numbers and kinds of game animals and birds killed during the previous year and were furnished with a card on which to keep an itemized record of the game killed under the new license. It is necessary to return these cards before any subsequent license is issued. In this way the license system is made the means of obtaining more nearly complete and accurate statistics than have hitherto been available. As stated in an interesting report by the conservation commissioner in a paper read before the International Association of Fish, Game, and Conservation Commissioners in 1918:

The paramount feature of New York's game census system is that it is founded upon definite observation and demonstrable facts. It should enable us to keep every wise law upon our statute books and to bring about changes

only as rapidly as actual changes in the conditions of wild life justify modification of the law.¹⁰

The returns for 1918 have recently been summarized by W. S. Carpenter, secretary of the commission, and the results made available, as shown in the following table:

Game taken in New York in 1918.

Species.	Total killed.	Individual value.	Total value.	Species.	Total killed.	Individual value.	Total value.
Cottontail rabbit...	465,590	\$0.50	\$232,795.00	Greater yellowlegs..	3,556	\$0.50	\$1,778.00
Muskrat.....	399,938	1.50	599,907.00	Lesser yellowlegs...	2,848	.50	1,424.00
Skunk.....	187,703	4.00	750,812.00	Gray fox.....	2,476	2.00	4,952.00
Gray squirrel.....	115,013	.50	57,506.50	Coot.....	1,974	.50	987.00
Duck.....	109,663	2.00	219,326.00	Goose.....	1,380	3.00	4,140.00
Grouse or partridge	41,757	2.00	83,514.00	Rail.....	1,328	.50	664.00
Snowshoe rabbit...	36,170	1.00	36,170.00	Golden plover.....	1,214	.50	607.00
Pheasant.....	35,855	3.00	107,565.00	Black-bellied plover	1,045	.50	522.50
Raccoon.....	25,349	5.00	126,745.00	Sable, or marten...	823	4.00	3,292.00
Woodcock.....	19,249	2.00	38,498.00	Otter.....	591	25.00	14,775.00
Red fox.....	15,156	15.00	227,340.00	Fisher.....	396	25.00	9,900.00
Wilson snipe, or jacksnipe.....	11,325	.50	5,662.50	Brant.....	241	3.00	723.00
Black squirrel.....	11,028	.50	5,514.00	Gallinule.....	216	.50	108.00
Quail.....	8,999	2.00	17,998.00	Bear.....	189	25.00	4,725.00
Mink.....	8,917	6.00	53,502.00	Bobcat.....	159	10.00	1,590.00
Fox squirrel.....	8,437	.50	4,218.50	Sora.....	82	.50	41.00
Deer (bucks).....	8,293	75.00	621,975.00	Total.....	1,526,960		3,239,277.00

In Canada several of the Provinces have attempted to collect statistics by requiring a return from hunters holding big-game licenses. This system has been in operation in Manitoba since 1905, in Alberta and Nova Scotia since 1907, in New Brunswick since 1908, and in British Columbia since 1913, and has furnished valuable figures regarding the numbers of big game killed. Experience has shown that ordinarily at first a large proportion of the licensees fail to make the return and that it is almost impossible to obtain figures from delinquents who are nonresidents or from residents who have moved or left the Province. Following are the figures for Nova Scotia:

Big game killed in Nova Scotia, 1908 to 1920.

[From report game commissioner for 1920, pp. 22-30.]

Year.	Deer.	Moose.	Year.	Deer.	Moose.
1908.....		1,688	1916.....	154	1,331
1909.....		405	1917.....	101	1,363
1910.....		509	1918.....	69	1,241
1911.....		617	1919.....	198	1,277
1912.....		678	1920.....	125	1,361
1913.....		704			
1914.....		1,095	Total.....	647	12,477
1915.....		1,208			

¹ Includes 240 cows.

¹⁰ Pratt, George D., Checking up New York's game resources: Bull. Amer. Game Protective Assn., vol. 7, no. 4, pp. 11-14, October, 1918.

One of the most complete records of this kind is that maintained by the Province of Alberta. Under a provision inserted in the law of 1907, each resident to whom a big-game license was issued was required to return the license to the Department of Agriculture immediately after the close of the season, accompanied by an affidavit showing the number of animals killed. Failure or neglect to return the license within 30 days after the end of the season constituted a violation of the game law and was ground for the refusal of a license in future. (The latter provision seems to have been modified or repealed in recent years.) At first these provisions were not generally known or strictly enforced, and consequently the returns fell far short of the actual number of animals killed, but as time went on they became more generally understood and the returns were fairly accurate though doubtless always somewhat below the actual number. The records obtained under this law for the 12 years 1907-18 are shown in the accompanying table, which also gives for comparison the total number of big-game licenses issued. The limits in Alberta have usually been one deer, moose, and caribou, and two antelope, sheep, and goats, a season.

Big game killed in Alberta, 1907 to 1918.

[From Ann. Rept. Dept. Agr. Alberta for 1919, p. 122.]

Year.	Deer.	Elk.	Moose.	Caribou.	Antelope.	Mountain sheep.	Mountain goats.	Total killed.	Total big-game licenses.
1907.	59	-----	14	-----	49	-----	-----	122	450
1908.	125	-----	37	-----	45	-----	-----	207	536
1909.	299	-----	86	5	89	40	38	557	1,179
1910.	540	7	184	8	126	54	46	965	2,021
1911.	619	-----	305	30	101	49	56	1,160	2,955
1912.	768	-----	425	40	105	90	58	1,486	3,988
1913.	908	-----	865	56	119	65	42	2,055	5,670
1914.	1,388	-----	1,335	78	-----	78	61	2,940	7,326
1915.	692	1	1,116	34	-----	110	40	1,993	5,959
1916.	560	-----	849	28	-----	83	26	1,546	4,185
1917.	705	-----	1,026	43	-----	57	37	1,868	4,852
1918.	828	-----	900	45	-----	76	43	1,892	4,953
Total..	7,491	8	7,142	367	634	702	447	16,791	44,074

ENUMERATIONS OF GAME.

After securing returns for statistics of big game and game birds annually killed, the next step is to estimate the total stock of each species within a certain State or area. Except for a few species of big game which have been reduced almost to the point of extermination, notably buffalo, elk, and antelope, it has been impracticable hitherto to obtain any comprehensive estimates of this kind.

The buffalo is now in a state of semidomestication, and it is a comparatively simple matter to ascertain its total numbers. Thirteen counts have thus far been made in the following years: 1889, 1903,

1908, 1910, 1911, 1912, 1913, 1914, 1916, 1918, 1919, 1920, and 1921. Briefly, they show that the total number of buffalo in existence has increased in 32 years from 1,091 in 1889 and 1,753 in 1903 to about 9,300 on January 1, 1921. These figures do not include the wood bison of Canada. The details of the first count were published in 1889 in Hornaday's "Extermination of American Bison" (p. 525); the second by the National Zoological Park; and the others in the annual reports of the American Bison Society.

In the case of antelope the Biological Survey published an estimate for the year 1908, based on the best figures then obtainable, showing a total of 17,000 in the United States, or, adding those in Canada, a total of less than 20,000 north of Mexico.¹¹

An estimate of the number of moose, made by the Biological Survey for 1910, showed about 3,050 in the northern Rocky Mountain region—in Idaho, Montana, and Wyoming.¹²

For mountain goats the Forest Service officials estimated that in 1910 the total number in the State of Washington, exclusive of the Mount Rainier National Park, was about 1,700, of which 700 were on the west slopes and 1,000 on the east slopes of the Cascades.

The New York Conservation Commission estimates the total number of deer in that State at about 50,000. No other State has attempted to collect the necessary data in as comprehensive a manner.

From the foregoing partial estimates it is possible to approximate roughly the total number of big game other than deer in the United States. The figures in the following table should be regarded merely as maximum approximations and not in any sense accurate estimates.

Estimates of total number of big game other than deer in the United States.

Kind of game.	1918	1920	Kind of game.	1918	1920
Buffalo.....	2,700	3,400	Mountain goats.....	6,000	6,000
Elk.....	72,000	52,000	Mountain sheep.....	11,000	10,000
Antelope.....	10,000	7,500			
Moose.....	6,000	7,000	Total.....	107,700	85,900

This total of about 86,000 for 1920 covers only the big game south of the northern boundary of the United States, latitude 49°, and does not include the game of Alaska or of any part of Canada. Consequently, more than 50 per cent of the buffalo of North America are omitted from the statement, as are a considerable number of elk, the great herds of moose and caribou, and thousands of mountain sheep. Of the 3,400 buffalo, 1,032 are in Government herds, 111

¹¹ Palmer, T. S., Progress of game protection in 1908: Yearbook, U. S. Dept. Agr., 1908, p. 582, 1909.

¹² Palmer, T. S., and Henry Oldys, Progress of game protection in 1910: Biol. Surv. Circ. 80, p. 11, 1911.

are owned by States, and the remainder are in private hands. The elk are chiefly confined to the northern Rocky Mountain region in the vicinity of the Yellowstone National Park, and in Arizona, Colorado, Idaho, Washington, and California. Of the antelope less than 500 are on Government game preserves and most of the others are in Montana, Wyoming, New Mexico, Nevada, and eastern Oregon. Moose are restricted to Maine, Minnesota, Wyoming, Montana, and Idaho. Mountain sheep are more generally distributed, the larger numbers now being found in Colorado, Montana, Wyoming, Arizona, and California. Mountain goats are confined to the Cascade region in Washington and to the mountains in western Montana and eastern Idaho.

It is of course impossible to estimate accurately the value of this big game. Some of the elk, moose, and sheep belong to species found nowhere else in the world and are now represented by small herds. Unlike most things which have a definite value, wild game can not always be replaced when it is exterminated over an area. No market value in the ordinary sense of the term can be placed upon such animals. If buffalo should be valued at \$200, antelope and moose at \$100, elk at \$75, and sheep and goats at \$30 each (all conservative figures, at least for animals for propagating purposes), the total value of the big game other than deer would be not less than \$5,000,000. Deer are much more abundant than any of the other kinds of big game, and with the figures available it is probably safe to estimate that their value is at least twice that of other big game. This would give a value of \$10,000,000 for deer and a total value of at least \$15,000,000 for all the big game in the United States, exclusive of Alaska.

METHODS OF INCREASING GAME RESOURCES.

Of the various methods of increasing game resources which have been suggested or put into practice in the United States, four merit special notice, namely, protecting game, establishing refuges, restocking depleted areas, and breeding on game farms.

The simplest method, and usually the first adopted, consists merely in protecting the native stock of game so as to allow it to increase naturally. This is done through legislation, by defining the seasons for hunting, regulating methods of capture, and limiting the amount that may be taken or the purpose for which it may be used; and through administration, by enforcing the various provisions of law. All of this work, which has occupied most of the attention of game departments, is in a certain sense negative, since, without any constructive action in the direction of increasing the stock, it merely seeks to prevent undue destruction.

In establishing game refuges the protective method is carried a step further by suspending all hunting on a given area and allowing the game to multiply without harvesting any of the annual increase. The surplus is allowed to overflow the surrounding region and thus improve hunting on the lands adjoining the refuge. When refuges of adequate size are properly selected and well stocked, this method proves very satisfactory. On the other hand, poaching is likely to occur, and, furthermore, the game, being subject to disease, to depredations of predatory animals, or to unfavorable climatic conditions, does not always increase at the rate anticipated.

By resorting to restocking, the first positive step is taken in directly increasing the amount of game by artificial means. This is done either by the transfer of native species from adjoining or distant regions or by the introduction of foreign species. Restocking has the advantage of arousing general interest, improving public sentiment toward game protection in a region, and enlisting the support of many persons who otherwise would take little or no interest in game conservation. It requires considerable funds, though money is usually more easily obtained for restocking than for warden service. The results, however, are not always satisfactory. In fact, the percentage of failures is much larger than in the case of experiments with refuges, mainly because many attempts at restocking have been ill-advised—species not adapted to a region have been introduced and insufficient attention has been given to details of capture, handling, and feeding.

On the theory that game can be produced like poultry or domestic stock, the game farm has been heralded in some States as the solution of the problem. It is sometimes asserted that, given so many dollars, so many pheasants may be produced for liberation. Simple as this method may seem, it has proved more difficult and more expensive than any of the others mentioned, and in several instances expense and lack of initial success have resulted in loss of interest on the part of the public and have ended, temporarily at least, in the abandonment of the project. Artificial game propagation is still in an experimental stage, and the kinds of birds which can be produced in large numbers with any degree of certainty are at present very limited. Failures are due most frequently to initial investments on too large a scale, to devoting time and money to birds the propagation of which is still in an experimental stage, and to attempts to produce too much stock in a limited time.

PROTECTION.

In the conservation of game in the United States more attention has been given to protection than to any other method. Probably three-fourths of the funds and of the effort have been expended in

this direction, mainly by regulating seasons and methods of hunting, limiting the amount of game which may be killed in a specified time, prohibiting export and sale, and providing means for administration chiefly through a system of licenses.

The first law regulating seasons and prohibiting export was passed nearly 250 years ago, in 1677, in Connecticut. Other forms of protection have been more recent. The first laws placing limits on the amount of game to be killed were enacted less than half a century ago, in 1878, in Iowa. Laws prohibiting the sale of all protected game are of as recent date as 1887 in Wisconsin, and were passed 10 years later in Kansas, Michigan, New Mexico, and Texas.

In regulating seasons certain principles are generally considered fundamentally important, but their application has been strongly resisted. Among these are the prohibition of summer shooting—that is, during the breeding season; the prohibition of spring shooting, while birds are on their way to the breeding grounds; and the protection of females of big game, particularly in the case of deer.

SUMMER SHOOTING.

Summer shooting has been most destructive in the case of woodcock, squirrels, and shorebirds. Owing to the fact that the woodcock breeds early, that the young are well developed before autumn, and that the birds migrate early, the custom developed years ago of opening the season in midsummer, in some States as early as July 4. This practice prevailed for many years and only recently has July and August woodcock shooting been abolished.

Squirrel shooting in summer has not yet been entirely stopped. Of the 38 States which protected squirrels in 1920, 6 permitted summer shooting as follows: Arkansas, beginning May 15; Missouri and Tennessee, June 1; Illinois and Kentucky, July 1; and Indiana, August 1.

Spring and summer shorebird shooting persisted along the Atlantic coast in some States until the passage of the migratory-bird law in 1913. The birds were shot not only on the northward flight in May but also as soon as they reappeared early in July. Under the present Federal regulations the season on such shorebirds as may be hunted opens as follows:

August 16 in the coast States of New England, and in New York, New Jersey, Delaware, Maryland, and Virginia;

September 1 in the District of Columbia, North Carolina, South Carolina, Tennessee, Arkansas, Oklahoma, Texas, New Mexico, Arizona, California, and Alaska;

September 16 in Vermont, Pennsylvania, Ohio, West Virginia, Kentucky, Indiana, Michigan, Wisconsin, Illinois, Missouri, Iowa, Minnesota, North Dakota, South Dakota, Nebraska, Kansas, Colorado, Wyoming, Montana, Idaho, Nevada, and that portion of Oregon and Washington lying east of the summit of the Cascade Mountains;

October 1 in Utah and in that portion of Oregon and Washington lying west of the summit of the Cascade Mountains;

November 1 in Georgia, Florida, Alabama, Mississippi, and Louisiana.

SPRING SHOOTING.

Notwithstanding the well-recognized fact that birds should not be killed during the mating season or while on their way to their breeding grounds, it has proved one of the most difficult problems of game protection to put an end to the practice of shooting waterfowl and other migratory birds in spring. The first law prohibiting spring shooting was passed 75 years ago, in 1846, in Rhode Island, but for half a century the movement made little progress. During the last 20 years a number of the Northern States have prohibited waterfowl shooting in spring, but the difficulty of eradicating the practice in some sections immediately became evident with the enactment of the migratory-bird law in 1913. No regulation was so strenuously opposed as that prohibiting shooting in spring, particularly in some of the States of the Middle West. The beneficial effects of diminishing if not entirely eliminating spring slaughter became apparent almost immediately and no feature of Federal protection of migratory birds has done more to increase the number of waterfowl than that prohibiting shooting when birds are on their northward migration.

PROTECTING FEMALES OF BIG GAME.

The importance of preserving the breeding stock by protecting females has long been recognized. With those species of big game in which the sex is easily distinguished, as in deer, elk, and moose, this can readily be accomplished by restricting the hunting to males. California, as early as 1883, protected does, and Colorado a few years later adopted the same policy. In the case of moose, it has been the practice to protect cows ever since Maine inaugurated it in 1891. The beneficial results of such a policy have since been demonstrated in some of the Provinces of Canada. At present moose hunting practically everywhere is restricted to bulls.

In the case of deer, legislation for the protection of does has made gradual though rather slow progress, and in some States it has met with strenuous objection. In 1920 about half the States which permitted deer hunting protected does at all seasons. More specifically, 33 States enjoyed deer hunting, and of these, 17 and the Territory of Alaska protected does (see map, fig. 1); and, as already stated (p. 16), this number was increased in 1921 to 23 States, exclusive of Alaska.

Doe laws are important not only in conserving the breeding stock of deer but also in protecting human beings, since the simple expedient of requiring a hunter to ascertain before shooting whether the

animal at which he aims has horns has been the means of saving many a human life. Comparatively few deer-hunting accidents occur in States which have doe laws, but notwithstanding this fact, such important deer-hunting States as Maine and Minnesota still allow the indiscriminate killing of bucks and does. In States like Pennsylvania and Vermont, where does have been protected for a number of years (although Vermont allowed killing for a time), the results have been so beneficial that the policy has gained general approval.

ESTABLISHING GAME REFUGES.

To replenish and increase their game resources, many of the States, by establishing State game preserves and refuges, have encouraged game animals and birds to breed under natural conditions. These reservations are (*a*) public hunting grounds or shooting preserves; and (*b*) game preserves or refuges. In addition, many States have experimented in game farms. Public hunting grounds, consisting of State lands where game is protected throughout the greater part of the year and where the public is allowed to hunt in the open season, have thus far been provided only in New York, Pennsylvania, Maryland, Michigan, and Louisiana. State game preserves have been established in nearly two-thirds of the States, including half of those east of the Mississippi River and all of those west of that river except Arkansas, Missouri, Nevada, and Texas.

PUBLIC HUNTING GROUNDS.

The most notable examples of public hunting grounds are the Adirondack Preserve, in New York; the Susquehanna Flats, in Maryland; the State forests in Pennsylvania; and the recently established Pass a Loutre shooting grounds in Louisiana.

The Adirondack Preserve now includes timber or cut-over lands in northern New York which have been acquired by the State. These lands, set aside primarily for forestry purposes and for the protection of the water supply, are open to the public for hunting during the open season and furnish the most extensive public hunting grounds in the country. Most of the deer hunting and much of the best grouse shooting in New York may be found within the Adirondack Preserve. This preserve has also been stocked with elk and other animals, but these species are rigidly protected and there is no open season during which they may be hunted.

The shooting grounds on the Susquehanna Flats, at the head of Chesapeake Bay, Md., constitute the oldest of the State game reservations, the regulations for the protection of the waterfowl having been enacted about half a century ago, in 1872. Within this area waterfowl shooting is regulated to a certain extent by special State laws, providing rest days, prohibiting night shooting, limiting the use of

sink boxes and decoys and requiring licenses for the use of such paraphernalia, and providing a special warden system. The proceeds from licenses are applied to the payment of salaries of the wardens, who are appointed directly by the governor and are more or less independent of the State warden.

The Pennsylvania system of preserves is unique; it consists of a number of small irregular areas on State lands, each not more than 9 miles in circumference and marked by a single wire fastened to the trees. No hunting is allowed within these areas and no one is permitted to enter the inclosures during the open season. Deer when pursued outside thus find a real refuge within the inclosure. At least 30 or more such refuges have thus far been established.

After an experience of several years the Pennsylvania refuges have proved very effective in maintaining and increasing the supply of deer in their vicinity. The State has 1,029,023 acres of State forests, which in effect furnish public camping and hunting grounds, much as the Adirondack Forest does in New York, with the difference that Pennsylvania is actively stocking and increasing the supply of deer through the medium of these small refuges, whereas New York relies entirely on regulating the hunting and on the natural increase of the stock, without resorting either to restocking or to maintaining natural refuges.

The most recent project of this kind is the Pass a Loutre public shooting grounds located in southern Louisiana at the mouth of the Mississippi River. This great waterfowl resort, comprising some 60,000 acres between Pass a Loutre and South Pass, is within easy reach of New Orleans and was opened to the public on November 1, 1921. It provides a place where 100 sportsmen may hunt at one time and that may be enjoyed by the public at a minimum of expense. Here the hunter who can not afford to belong to an exclusive duck-hunting club may enjoy the same advantages of wild-fowl shooting as a club member merely at the cost of his hunting license, a permit from the conservation commission, and his actual expenses while shooting on the reservation. The principal kinds of ducks to be found during the season are mallards, pintails, spoonbills, gray ducks, canvas-backs, redheads, teal, and lesser scaups. In creating this reservation Louisiana has set an example, which will doubtless be followed by other States, in utilizing and developing some of her marshlands for the benefit of the public rather than permitting them to pass into private ownership or allowing the shooting rights to be monopolized by a few private clubs.

Several years ago Michigan enacted a measure providing hunting grounds on Saginaw Bay, but nothing practical seems to have been accomplished by this legislation. A former game commissioner of Utah advocated a provision for public hunting grounds on lands in

Salt Lake, Davis, and Box Elder Counties, but this project has not thus far been carried out.

GAME REFUGES.

The object of establishing game refuges in places where certain birds and animals may receive protection throughout the year, is to permit native species to increase under natural conditions and thereby to restock surrounding territory. In recent years many experiments have been made in establishing State game refuges, both on public and on private lands. The State refuge of to-day is a comparatively modern institution. One of the oldest and best known reservations is the Teton State Game Refuge in Wyoming, established in 1905. Refuges differ widely in character, in area, and in the methods by which they are administered. Some are on Federal lands, some on State lands, and some on private lands, the private lands being held under contract for the purpose of game protection and being posted by the State. In size they range from a few acres to reservations containing several hundred square miles. One of the largest refuges in the United States is the Superior State Game Refuge in Minnesota, comprising in part Federal lands in the Superior National Forest and in part adjacent State and private lands. The States which have the largest aggregate areas devoted to game refuges are California, Minnesota, and Wyoming; those which have the greatest number of individual refuges are probably Michigan and Pennsylvania. Michigan has 50 or more and Pennsylvania has 32 of a peculiar type already described.¹³ The development of the refuge policy in Pennsylvania is interesting. In 1905 the State game commission received authority with the consent of the commissioner of forestry to establish game preserves on State forest lands; in 1907 the area of a reserve was limited to a tract 9 miles in circumference, and in 1911 the size was increased, provided the greatest diameter did not exceed 10 miles and the area was not greater than that of half the forest reservation on which located.

In most cases insufficient time has elapsed to determine the most successful type of preserve or to learn the ultimate success of some of the projects which have been suggested, but in Pennsylvania, Wyoming, and Indiana data are now available showing actual experience with widely different types of preserves over a period of several years.

Wyoming was one of the pioneer States in the establishment of State game refuges and now (1921) has 13, the combined areas of which are perhaps not greater than the total area of State reserves in California or Minnesota, yet individually each is of considerable

¹³ For a description of the Pennsylvania refuges, see Phillips, John M., Pennsylvania game preserves: In the Open, vol. 3, pp. 41-44, November, 1912.

size.¹⁴ These refuges are all established on public lands, most of them within the boundaries of national forests. The Teton Reservation, lying immediately south of the Yellowstone National Park, was the first and originally the largest. It was created in 1905, and embraced practically all the area immediately adjoining the south boundary of the park between the State line on the west, Buffalo Fork on the south, and the West Fork of the Yellowstone River on the east. In 1913 the boundaries were modified so as to eliminate the western part of the reservation between the Idaho line and the summit of the Teton Range. This elimination was due to the fact that most of the game on the west slope of the Tetons had been destroyed and the expense and difficulty of patrolling this remote region was not commensurate with the advantages gained. At the same time an addition was made in the southeast by extending the eastern part of the refuge up the Du Noir Creek. In 1917 another modification was made by eliminating the northeast corner of the refuge, including all the land north of Soda Creek and east of a straight line drawn from the junction of Soda Creek and the North Fork of the Buffalo north to the Continental Divide. The object of this change was to afford a larger hunting area for sportsmen from northern and central Wyoming by giving them hunting grounds between the Yellowstone River and the Continental Divide.

Thus in a period of 12 years the boundaries of the Teton Game Preserve have been changed three times and its original area, comprising about 576,000 acres, has been materially curtailed. The western section has been eliminated and the eastern boundaries have been first extended, then curtailed. While they still include the lower lands in the southeastern part of the refuge, this section lies in the form of a wedge extending at right angles to the general line of migration of the elk and is of little value, inasmuch as the elk can easily be driven out of it to open lands.

Two elements are essential for the success of any game refuge: First, permanency; and, second, sufficient area in a compact body. For the protection of big game, long narrow strips of territory are comparatively worthless and constantly shifting boundaries furnish little actual protection.

The Indiana game refuges, all established on private lands under contract with the owners, represent the other extreme from those of Wyoming. The idea was conceived and put into execution by the late Z. T. Sweeney, commissioner of fisheries and game from 1899 to 1911. Under his plan contracts were entered into between the State game commissioner and owners of contiguous farms providing

¹⁴ Under recent orders of the game and fish commission some hunting is permitted on the Big Horn, Popo Agie, and Split Rock Special Game Preserves.

that if owners would forego the privilege of hunting on their own lands the State would post such lands as State game preserves and stock them with game birds. No preserves were established unless agreements could be made with the owners for at least 400 acres of land forming a solid body nor for areas larger than 3,000 acres. In 1909 the State legislature passed an act affording a certain measure of protection to these preserves. This law provided:

That it shall be unlawful for any person in the State of Indiana for and during the term of six (6) years from and after the passage of this act to injure, take, kill, expose, or offer for sale, or have in possession, except for breeding purposes, any prairie chicken, any ring-neck Mongolian pheasant * * * or Hungarian partridge; or to hunt upon any game preserve organized or stocked with any of the above mentioned birds by the commissioner of fisheries and game: *Provided*, That any landowner living within the territory of the preserve may be permitted to hunt squirrels and rabbits on his own land only. (Laws of 1909, chap. 103, approved Mar. 6, 1909.)

In 1911 the commissioner referred in the following terms to the experiment of introducing Hungarian partridges, which began in 1909, and for which the system of preserves had been partly established:

There are now in the state 240 of these preserves, and they inclose in all something like 1,500,000 acres of protected breeding grounds for game birds. In most of the counties there are as many of them as there ought to be. * * *

By the first of the year 1910 Mr. Sweeney had established about 170 of these preserves, and on them he placed some 3,000 pairs of Hungarian partridges. Recent reports from them, with three or four exceptions, have been that the birds have done well during the past season, and that a great many broods have been hatched and reared on them. (Bien. Rept. for 1909-10, pp. 99-100.)

In March, 1915, this law expired by limitation, and in reviewing its history the commissioner of fisheries and game referred in his report in December, 1916, to the fact that there was at that time no game preserve law in effect. He further stated:

The provisions of this law were so indefinite and inadequate that the preserves established under its provisions were not the success they should have been. In many cases, it is claimed, the owners of the lands which were included in the preserve used the "State game preserve" signs to keep others out, and made it a private hunting ground. * * *

A few years ago a large sum of money, approximately \$70,000, was expended in the purchase of Hungarian partridges and English ring-neck pheasants, which were distributed throughout the State, most of them being planted on game preserves which were then in existence. To-day very few of these birds are left. They not only failed to increase in number, but those that have survived constitute only a small per cent of the original stock planted. That the experiment was unsuccessful is beyond question. Very little satisfactory information as to why this was so can be obtained. (Bien. Rept., 1914-15, pp. 54-55.)

RESTOCKING DEPLETED AREAS.

No field of conservation is more important than the restoration of game in regions where it has been reduced to the vanishing point or completely exterminated. Plans for bringing back the game usually involve legislation, introduction, or propagation.

Legislation is the most popular method, and while indispensable in combination with others, it is the most disappointing when relied upon exclusively. Legislation failed to save either the buffalo or the passenger pigeon and can not by itself save any game after a species has been reduced beyond a certain point. Nevertheless, when enacted in time it not only may save the game but may result in its increase beyond normal conditions. Striking illustrations of the efficiency of legislative protection are afforded by the history of deer in Pennsylvania and of mountain sheep in Colorado. In recent years under a consistent and conservative policy of conservation in Pennsylvania deer have increased to such an extent that about 4,000 are obtained during the open season. Colorado has maintained a close season on mountain sheep ever since 1885, with the result that these valuable game animals have not only increased but the sentiment in regard to their protection has changed to such a degree in certain sections, notably near Estes Park, that every effort is made by the public to prevent them from being destroyed, and during severe winters the animals are systematically fed.

For many years efforts have been made to increase the stock of certain kinds of game by introducing species from other sections of this country or from abroad. Experiments have been made with many species, but the most important work has been done with quail. Hungarian partridges, pheasants, deer, and elk.

RESTOCKING WITH GAME BIRDS.

Quail.—The earliest efforts to increase the stock of quail in America were directed toward the introduction of the Messina, or migratory, quail (*Coturnix coturnix*) of Europe. These experiments began in the seventies and were continued for several years. Thousands of birds were imported and liberated at various points in the Eastern States, especially in the New England and Middle Atlantic States. Much money and considerable effort were spent in the attempt to acclimatize the birds and establish them in suitable places, but without permanent result. The birds were migratory and, although they seemed to thrive for a few months, when liberated they eventually died or disappeared and the experiment was a failure.¹⁵ About 1895, when an Asiatic species of quail of the same genus (*Coturnix*

¹⁵ Notes on these experiments in 1879, when nearly 3,000 quail were distributed, will be found in *Forest and Stream*, vol. 12, pp. 371, 412, 1879.

japonica) was being imported from China for the San Francisco market, some sporadic efforts were made to acclimatize the birds in California. These quail were imported alive in large numbers and it was easy to obtain stock at certain seasons, but like the Messina quail they were migratory and the experiment of introducing them as a game bird proved a failure.

The plan of introducing Old World quail having proved unsuccessful, efforts were made to obtain native stock from States where quail were still abundant. In the late nineties large numbers of quail were shipped east, north, and west from Kansas and Indian Territory. The demand for these birds grew to such an extent that it was impossible to supply the market, and the States where the birds were captured, fearing serious depletion of the stock, prohibited export. In 1907, the last year in which any considerable number of quail were captured for shipment in the United States, a disease, commonly known as quail disease (*Colibacillosis tetraonidarum*), was discovered in a number of consignments sent to points in the North and East from Alabama and the Southwest. Three or four years later, because of the scarcity of native birds, efforts were made to obtain stock in northeastern Mexico, but each season, notwithstanding the precautions and quarantine regulations, quail disease appeared in some of the shipments. In the winter of 1916-17 the importations of Mexican quail totaled 32,814; about half of these birds were obtained by the game commissions of two northern States and more than 50 per cent of them died soon after they were distributed. In the winter of 1919-20, 864 birds imported died in quarantine or were returned to Mexico because they were infected with quail disease. Many others died after reaching their destinations. The total number entered that season was 22,209.

Hungarian partridges.—The difficulty in securing an adequate supply of native quail encouraged importers to endeavor to meet the deficiency by bringing in the European gray partridge (*Perdix perdix*) under the name of Hungarian partridge. The advantages of introducing the bird were widely advertised and a thriving trade was developed by a few importers. Game commissioners and game protective associations were induced to liberate the birds in as large numbers as the funds at their disposal would permit. In some instances favorable reports of the success of these experiments were made for the first year or two after the birds were liberated, but in most States the introductions were unsuccessful except in eastern Washington. The birds usually sold for \$5 or \$6 per pair, and from 1906 to 1915 many thousands were imported. High-water mark was reached in 1914, when 36,760 were brought in, while the total number imported during the decade was 174,294. Thousands of dollars were expended, but comparatively few partridges can now be found in

sections where many birds were liberated a few years ago. For example, the State of New Jersey, which purchased partridges liberally for several years, ceased the distribution in 1912. Four years later investigation showed a total of 45 coveys with about 490 birds in the State, while in 1918 the number had decreased to 23 coveys with a total of 115 birds.

Pheasants.—For 40 years pheasants have been imported and liberated in varying numbers in many parts of the country. The success of the introduction of the so-called ring-necked pheasant, first imported in Oregon in 1887 and 1888, and the success with English and ring-necked pheasants in the Genesee Valley, N. Y., and in some sections of Massachusetts, encouraged other States to undertake similar experiments. Pheasants and pheasant eggs were imported in considerable numbers from Europe, chiefly from England, and in recent years from several points in Ontario, but with the beginning of the war these shipments rapidly diminished and comparatively few birds have been brought in since. Notwithstanding the suspension of importations, there are more pheasants in the United States now than ever before, and nearly all are the product of stock raised in the United States. In many places the bird has become well established and in a few States sufficiently abundant to permit an open season for a limited period in the autumn, notably in Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, and Washington, and formerly in Oregon.

The following table shows the importations of the principal upland game birds from 1906 to 1915, inclusive:

Importation of principal upland game birds, 1906 to 1915.

[Fiscal years ending June 30.]

Year.	Quail. ¹	Hungarian partridges.	Pheasants.	Year.	Quail.	Hungarian partridges.	Pheasants.
1906.....	2,896	864	1,151	1912.....	7,570	23,181	15,412
1907.....	1,428	3,075	4,970	1913.....	2,936	10,283	9,417
1908.....	649	7,781	4,420	1914.....	.....	36,760	4,148
1909.....	868	29,832	² 2,268	1915.....	3,341	7,080	15,841
1910.....	1,379	18,932	9,496				
1911.....	3,110	36,507	13,398	Total....	24,177	174,295	80,521

¹ Importation of quail from Mexico began in 1910 and the figures in the above table refer mainly to Mexican birds. The number imported in 1916 was 8,000; in 1917, 32,814; in 1918, 5,205; in 1919, 4,358; in 1920, 23,473; and in 1921, 22,209. In all, about 115,000 Mexican quail have been imported in 11 years.

² 1,100 aviary pheasants.

RESTOCKING WITH DEER.

Deer increase so rapidly when given adequate protection that there has been comparatively little necessity for general restocking except in a few places. Two of the experiments thus far made, in New Jersey and Vermont, have met with such success as to attract widespread attention.

In 1899 a close season on deer for 10 years was provided in New Jersey and a number of deer obtained through the game commission were liberated in suitable sections of the State. When the season opened in 1909 hunting was limited to bucks and restricted to one day, Wednesday, in each week in November; later the season was opened for four or five days. In 1915 the season was opened on both bucks and does, and 293 of those killed were does. The following is a record of 3,626 deer killed in 12 years:

Deer killed in New Jersey, 1909 to 1920.

Year.	Deer killed.	Year.	Deer killed.
1909.....	86	1915.....	503
1910.....	127	1916.....	255
1911.....	¹ 171	1917.....	327
1912.....	² 109	1918.....	353
1913.....	149	1919.....	522
1914.....	180	1920.....	³ 844

¹ 30 illegally.

² 5 illegally.

³ 10 illegally.

In comparison with the results elsewhere the number of deer annually killed in New Jersey is small, but as the area there available for deer is limited and the season short, the discrepancy in the results is not so great as would appear at first sight. In Vermont the total number of deer killed during the first 10 open seasons was 3,489, and the daily average was about 58; while in New Jersey the total number was 2,260 and the daily average was 56, but in New Jersey the large number killed in 1915, and the correspondingly high daily average, were due to the fact that nearly 60 per cent of the deer killed were does.

The experiment of reintroducing deer into Vermont merits special attention, because it has been a marked success and because the records are sufficiently complete to make it possible to trace each step in the work. Sixty years ago deer were practically extinct in the greater part of Vermont, except in Essex County in the northeastern corner of the State. At that time the Rutland County sportsmen undertook the task of restoring the deer. Funds were collected, 17 deer were obtained from various sources, chiefly from Dannemora, N. Y., and liberated in the county, and in 1865 a close season of 10 years was established by the legislature. Since 1876 the close season has been extended from time to time so that the deer enjoyed almost uninterrupted protection for 32 years, from 1865 to 1897, except during the open seasons of 1875 and 1876. In addition, a standing reward of \$50 was offered for evidence which would lead to the conviction of anyone violating the law. Under this protection the deer increased rapidly and spread throughout the State and also into adjoining States.

Nearly a quarter of a century has now elapsed since the season was first opened, and the results of the experiment can be appraised more accurately than those of almost any similar work in the country. Not only has a record been kept of the number of deer killed during the short open seasons each year but there is a record of the deer reported killed by dogs, by accident, and illegally. In round numbers about 41,000 deer have thus far been killed during the hunting seasons from 1897 to 1920, inclusive, and about 3,200 by accident, out of season, etc.; in other words, all together, an average of about 1,845 deer have been shot during each of the 24 years. During the first decade only about 10 per cent of the total number were obtained, but in recent years the annual deer crop has increased rapidly. The number killed each year during the open season or otherwise is shown in the following table, the figures for deer killed illegally, by accident, etc., being for the biennial term ending June 30 of the year following date in which the entry appears:

Record of deer killed in Vermont, 1897 to 1920.

Year.	Killed in open season.	Killed illegally, by acci- dent, etc.	Year.	Killed in open season.	Killed illegally, by acci- dent, etc.
1897.....	103	.....	1910.....	3,609	.....
1898.....	134	.....	1911.....	2,644	432
1899.....	90	70	1912.....	1,692	.....
1900.....	123	.....	1913.....	1,802	298
1901.....	211	39	1914.....	2,025	.....
1902.....	403	.....	1915.....	6,042	234
1903.....	753	357	1916.....	1,630	.....
1904.....	541	.....	1917.....	¹ 981	¹ 36
1905.....	497	294	1918.....	825	.....
1906.....	634	.....	1919.....	4,092	136
1907.....	991	609	1920.....	² 4,440	.....
1908.....	2,208	.....			
1909.....	4,597	714	Total.....	41,067	3,219

¹ Sportsmen's Review, vol. 52, p. 543, Dec. 15, 1917.

² Field and Stream, vol. 26, p. 295, July, 1921.

Three factors—limits, sex, and seasons—enter into the consideration of these figures. The first year the season was open each hunter was allowed to kill two deer, but since 1898 the limit has been reduced to one. The killing has been restricted to bucks except in 1909, 1910, 1915, 1919, and 1920. The abnormally large numbers of deer killed in these years were evidently largely made up of does. In 1910, when an exact record was kept, the numbers were 1,749 does of an average weight of 146 pounds and 1,860 bucks of an average weight of 174 pounds; and in 1919, 2,138 does and 1,954 bucks. In 1918 the average weight of both bucks and does was 177 pounds and in 1919 the average was 140 pounds. The suspension of the doe law in 1915 evidently proved disastrous to the species, as shown by the greatly reduced number obtained the following year, a number less than that obtained in any previous season for eight years.

The hunting season was originally open during the whole month of October, but after the first year was shortened to the last 10 days in the month. From 1905 to 1910, inclusive, the season was further shortened to the last 6 days in October, except in 1908, when it was postponed until the second week in November on account of the drought and consequent danger from forest fires. In 1911 the season was lengthened and made later to include the 10 days from November 15 to 25. In 1913 it was again lengthened, this time to the last 3 weeks in November; in 1915 the opening date was again postponed to November 15; in 1917 the season was 9 days, November 10-20; and finally in 1919 it was made the first full week in December. In all the changes an increasing effort is apparent on the part of those in favor of hunting to kill more and more deer, either by lengthening the season or shifting it to the most favorable dates, and occasionally by taking advantage of local prejudice due to damage done by deer, to gain temporarily the privilege of killing does. In 1919 the legislature authorized the fish and game commissioner on application of the owner to establish orchard zones around commercial orchards of 10 acres or more where deer could be killed at any time. During the first year nine such zones were established and the number of deer killed was 49.

Three other examples deserve mention in this connection, although the restocking has been done by natural rather than by artificial means. In Pennsylvania, through a judicious system of protection, deer have increased rapidly, and in addition to the native stock considerable numbers have been liberated for restocking preserves and counties where deer had become scarce. Some of the animals were obtained from local preserves and others were imported from northern Michigan. In Massachusetts deer have repopulated the State to such an extent that an open season of six days has been provided for several years. When the season was first opened in 1910, 1,281 deer were killed; during the same year the number killed on account of damage to crops or for other causes was 598, making a total of 1,879 killed during the year. In Nova Scotia deer have increased remarkably in recent years. They were not originally native in the Province, but have spread eastward from New Brunswick. Apparently the first deer was killed in December, 1886. Soon after a continuous close season was placed on the species, and when the season was first opened in 1916, 154 bucks were killed.

RESTOCKING WITH ELK.

The most successful experiments in restocking areas with big game have been the transfers of elk from the Yellowstone National Park and Jackson Hole, Wyo., to various points in the United States.

These transfers began in 1910,¹⁶ and for the first two years were merely on an experimental basis. Beginning in 1912, several hundred elk were shipped each year under Federal and State auspices, and the total number distributed during the last 12 years has been about 4,000. Methods of capture and transportation have been greatly improved and costs of transportation reduced, and the losses have been comparatively small, probably not more than 10 per cent. In some cases elk have been transferred from the Yellowstone Park to Eastern States without any loss en route. The greater number of the animals were obtained from the northern herd in the Yellowstone Park and shipped from Gardiner, Mont. A smaller number were captured in Jackson Hole, transported over the Teton Pass on sleds to the railroad at Victor, Idaho, and thence

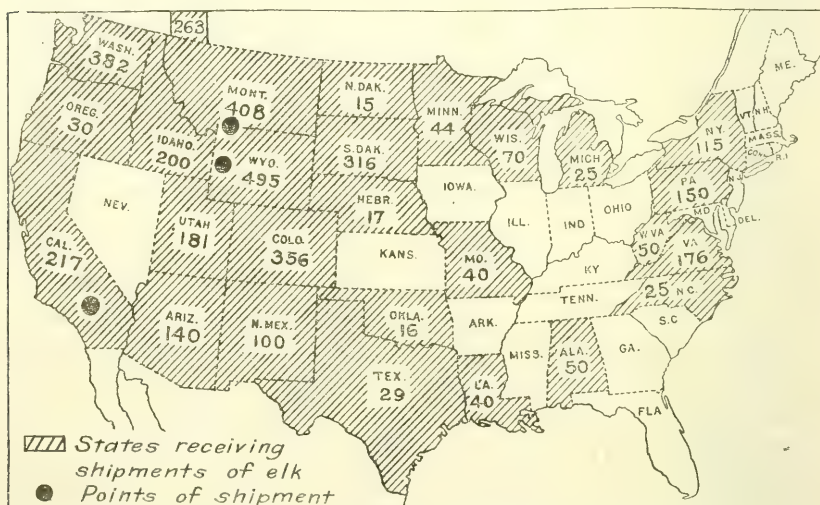


FIG. 4.—Elk shipments for restocking purposes. Spots indicate points of shipment; shaded areas, the States receiving elk; and figures, the total number of elk received by the States and Canada.

shipped to their destination. Shipments thus far made to 25 States and Canada (see map, fig. 4) may be roughly divided into five groups: (a) From the Yellowstone National Park to other States; (b) from the park or near-by points in Montana to other sections in the State; (c) from Jackson Hole, Wyo., to other points in the State; (d) from Jackson Hole, Wyo., to other States; and (e) from Buttonwillow, Calif., to other points in the State.

As a rule these elk have done well in their new locations; already a number of new herds have been well established, and in the course of a few years they should increase to considerable proportions. As might have been expected in transferring so many elk, some of the locations selected have been ill-advised and complaints have been

¹⁶ The first transfer was actually made in 1905, when a small herd of valley elk was moved from Buttonwillow in the San Joaquin Valley, Calif., to the Sequoia National Park.

made of the damage done to farms in the neighborhood, calling for the transfer of these herds to new locations. The number of such mistakes, however, has been small. The following tables give a summary of all elk transferred and the destination of the elk transferred each year.

Summary of all elk transfers, 1905 to 1920.

[Fiscal years ending June 30.]

Year.	By Federal authorities.			By State authorities.		Total.
	From Yellow-stone Park.	From Jackson Hole.	From other points. ¹	From Jackson Hole.	From other points. ¹	
1905.....			21			21
1910.....				28		28
1911.....		12				12
1912.....	137	63		134	200	534
1913.....	538	100	17	210		895
1914.....	99	140		80	54	373
1915.....	375				92	467
1916.....	618					618
1917.....	496					496
1918.....	135					135
1919.....	100					100
1920.....	339					339
Total.....	2,837	315	38	482	346	4,018

¹ Miscellaneous shipments originated as follows: Federal—1905, California; 1913, Nebraska; State—1912, Montana; 1914-15, California.

² In the Jackson Hole shipments of 1912, 12 head were sent to Minnesota and the others to Wyoming.

Destination of all elk transferred, 1905 to 1920.

[Fiscal years ending June 30.]

[illegible]

GAME BREEDING.

STATE GAME FARMS.

In recent years a number of efforts have been made in several States to increase the amount of game by propagation and by the distribution of certain kinds of game birds. Propagating plants, commonly known as game farms, have been established under State auspices for the purpose of producing as many birds as possible. Some of these farms have been operated in connection with fish hatcheries, others have been established as independent organizations.

The kinds of birds which can be propagated in any considerable numbers are necessarily limited. Pheasants, chiefly ring-necked and English pheasants, are the ones most commonly raised, and a few of the other species, such as silver, golden, Lady Amherst, and Reeves, are produced on a small scale, mostly for exhibition. Mallards and black ducks, wood ducks, and wild turkeys are also raised in considerable numbers.

Among the more important game farms have been those established in Massachusetts, Connecticut, New York, New Jersey, Delaware, Ohio, Illinois, Minnesota, Missouri, Iowa, Oregon, and California. In several cases the farms have been abandoned after a trial of a few years on account of the expense involved or because the results were unsatisfactory. Ohio abandoned the raising of pheasants about 1902, but has recently again taken up the propagation of game birds. The most extensive game farm thus far established was probably that of Illinois, near Auburn, 16 miles south of Springfield, established in the spring of 1905, and abandoned about 1915.

The California game farm raised pheasants and also experimented to some extent with wild turkeys imported from Mexico. The Illinois farm raised numbers of English call-ducks for distribution among sportsmen interested in duck shooting, chiefly along the Illinois River. The Massachusetts commission has experimented in raising quail and ruffed grouse in captivity, but this work has not yet reached large proportions and the raising of ruffed grouse is still in an experimental stage. Much good work has been done at the New Jersey State game farm near Toms River, where pheasants, quail, and rabbits have been propagated. The most extensive State farms now in operation are those in New York, of which there are three—at Brownsville, Jefferson County; Sherburne, Chenango County; and Middle Island in Suffolk County. In 1919 these farms distributed 9,206 half-grown birds and 55,400 eggs for propagation.

The whole question underlying the successful operation of game farms is whether birds can be produced more cheaply under State auspices than they can be bought from private breeders. Advocates of game farms assert that game can be produced as economically on a

State game farm as it can be purchased in the open market, and furthermore that it is not always possible for the State to obtain the necessary stock of birds if dependence is placed upon open-market purchases. The factors which militate against the attainment of this ideal are frequent changes in administration, the question of labor, and the constant pressure for immediate returns. Changes in administration of game departments prevent consistent development of definite policies and encourage the adoption of temporary methods which promise showy results; the limitation on hours of labor, and the necessity of hiring foremen and superintendents who have no permanent pecuniary interest in the success of the farm greatly increases the cost of maintenance; while the demand for immediate results causes efforts to be made beyond the capacity of the plant, and tends toward the distribution of immature stock. The distribution of eggs or of birds only a few weeks old makes a showing in numbers, but the percentage of loss is very high, so that the ultimate benefit to the public is much less than if a smaller number of birds had been raised to maturity before being liberated. This factor also renders difficult a fair comparison of results on State and private farms. Owing to the high initial cost of establishing a farm and the short time in which most game farms have been in operation, data are not yet available to determine definitely whether it is economical for the State to raise its own birds.

PRIVATE GAME FARMS.

The breeding of game on private farms, particularly the breeding of game birds, has made rapid progress in recent years and gives promise not only of becoming an important factor in increasing the supply of game, but of establishing an important industry. Already the game breeders number several hundred, a journal devoted to their interests has been established, a game breeders' convention is held in New York each year, and a course in practical game breeding has been provided at Cornell University.

In addition to work done by the State game farms already mentioned, many persons are now propagating pheasants and waterfowl, and with the spread of interest in this work the hope increases of raising some kinds of game in sufficient numbers to make it abundant in certain localities. At least one private pheasantry has raised 10,000 birds a year, and several breeders have raised a thousand or more wild ducks. When this work has increased tenfold an enormous number of birds will be available for liberation each year. Since the beginning of the war the importation of pheasants and other game birds for propagation has fallen off rapidly and nearly all the stock on the market in the United States is raised in this country.

Most persons interested in this work are engaged in raising pheasants, some in rearing waterfowl, and a few in raising wild turkeys. Attempts to raise quail, ruffed grouse, and prairie chickens in captivity have met with some success, but have not as yet progressed beyond the experimental stage. What is now needed is the development of simple methods of rearing these birds so that those who have had experience in raising poultry may engage in raising quail, grouse, wild turkeys, wood ducks, wild geese, and other native species in sufficient numbers to render the venture successful from a commercial standpoint. The demand for such game is greatly in excess of the supply, and the market is capable of being developed enormously provided the game can be produced cheaply enough to be sold at reasonable prices.¹⁷

COST OF MAINTAINING GAME.

COST OF WARDEN SERVICE.

The principal expense connected with the protection of game is the maintenance of a patrol adequate to prevent violations of the laws. The growth of the warden service has developed steadily in the last few years, and in some States the development has been rapid. Until recently wardens were paid part of the fines, but this system, always unsatisfactory, has now been abandoned in most States. The next step was payment by the day when actually employed; this method is still followed by some States but fails to produce satisfactory results, as it is impossible to maintain an efficient force when men are uncertain of their pay and must rely on other employment to eke out their incomes. The third step, the employment of salaried wardens throughout the year, is the most satisfactory method thus far devised and makes it possible to develop a permanent and efficient force.

Wardens' salaries are now paid mainly from receipts from hunting licenses, and in many States the income from this source is sufficient to make the warden service self-supporting without cost to the general tax payers. The total cost to the State for such service depends chiefly on the amount of the salary and the number of the wardens. The salaries formerly paid deputies or field men were at the rate of \$50 or \$60 per month, but several States now pay from \$100 to \$125 per month, the rate being graded according to the character of the work and the experience of the men. District or supervising wardens receive more, and in New York the chief game protector receives a salary of \$5,000 per annum.

¹⁷ The Department of Agriculture has issued two bulletins on the propagation of wild-duck foods, which may be had on application: McAtee, W. L., Eleven important wild-duck foods; Bull. 205, pp. 25, figs. 23, 1915. McAtee, W. L., Propagation of wild-duck foods; Bull. 465, pp. 40, figs. 35, 1917.

New York, which has the most completely organized warden force of all the States, in 1919 had 125 game protectors under a chief protector, a deputy chief protector, and several inspectors. The total cost of the service in the year ending June 30, 1919, was \$323,265.19. Of this amount, \$180,166.21 was expended for salaries of protectors; \$9,976.50 for wages; \$88,909.40 for traveling expenses; \$3,434.19 for expenses of prosecutions; \$7,679.57 for operation of launches; \$12,472.13 for printing; \$10,596.40 for equipment and supplies, including hunters' buttons; and \$10,030.79 for miscellaneous items. The law provided for the appointment of 131 game protectors in 1920 at \$1,200 to \$1,500 each; 12 inspectors at \$1,800 each; a deputy chief game protector at \$3,000; and a chief protector at \$5,000. The salary roll authorized for these officers amounted to from \$186,000 to \$226,100. With allowances for traveling expenses, operation of launches, and miscellaneous items, the total expense authorized for warden service was fully \$350,000. On the other hand, receipts from hunting and other licenses and miscellaneous income from fish and game for the fiscal year 1919 amounted to \$382,499.

COST OF GAME REFUGES.

NATIONAL GAME REFUGES.

In any consideration of the matter of the cost of game refuges, whether national, State, municipal, or private, it is important to distinguish between the original cost of establishment and the expense of maintenance. In the case of national refuges comparatively little has been expended in the purchase of lands, as most of the areas originally belonged to the Federal Government, but there have been some expenses for inclosing or for stocking them. In four cases it was necessary for the Government to purchase the areas on which the reservations are now located. The land for the National Bison Range, on the former Flathead Indian Reservation, Mont., was purchased from the Indians in 1908 at a cost of \$30,000; and the expense of inclosing it and making it ready for game brought the total cost to approximately \$50,000. In establishing the winter Elk Refuge, in Jackson Hole, Wyo., it was necessary to purchase some tracts which were already under cultivation in order to obtain lands on which hay could be raised for the animals, and for this purpose Congress made appropriations aggregating \$50,000. In the case of the game preserve in the Wind Cave National Park, S. Dak., to secure an adequate water supply it was necessary to acquire a small private holding within the park and some additional land adjoining the northern boundary, and about 456 acres, purchased for this purpose at a cost of \$9,880, were thus added to the park. Recently, the Pisgah Game Preserve, in the Appalachian Forest in North Carolina, was

located on private lands purchased under the Weeks Act for watershed protection.

Congress has made several special appropriations for inclosures or other improvements in establishing refuges to provide for game acquired by donation or otherwise. In 1902, an appropriation of \$15,000 was made for the Yellowstone National Park for purchasing a herd of buffalo (20 head), constructing a suitable inclosure, and meeting incidental expenses of installation. In 1906, \$15,000 was appropriated for constructing a fence on the Wichita Game Preserve, Okla., and in 1913, \$2,000 for erecting suitable headquarters. In 1910, an appropriation of \$26,000 was made for the improvement of the Wind Cave National Park, by the establishment of a game preserve, including the acquisition of the lands above mentioned. For the Sullys Hill Park, N. Dak., there have been five appropriations of \$5,000 each for improvements, including fencing, constructing headquarters, roads, etc.

The cost of maintenance of the various reservations is very moderate. The annual appropriation for the care of the buffalo in the Yellowstone Park until recently has been \$3,000 (later \$5,000), and a small appropriation is made for the Wichita Game Preserve. Most of the other mammal and bird refuges under the charge of the Department of Agriculture, including 5 big-game refuges and 65 bird reservations, have been maintained for several years under an annual appropriation of approximately \$35,000, increased to \$39,735 for 1921. During the spring of 1920 emergency appropriations amounting to about \$75,000 were made for feeding elk in the Yellowstone National Park and in Jackson Hole, Wyo.

STATE GAME REFUGES.

In marked contrast with provisions made in connection with national refuges, States seldom make any expenditures for lands on which to establish game preserves, although liberal appropriations are made for game farms. In providing for improvements where necessary, or for costs of maintenance, much more liberal appropriations are made as a rule than in the case of national reserves. State refuges are usually located either on lands acquired by the State or on lands which have reverted to it through nonpayment of taxes, or occasionally, as in South Dakota, through exchange with the Federal Government for school lands within Government reservations in other parts of the State. In New York, Pennsylvania, and Wisconsin the lands have been purchased by the State primarily for forestry purposes, and not chiefly for the establishment of game reserves. In Louisiana an area of about 15,000 acres on Vermilion Bay has been donated to the State for a game reservation. More recently the great Marsh Island and Rockefeller Preserves have also been donated to

the State, and a large area in another parish has been placed at the disposal of the conservation commission for experiments in game protection, including the introduction of elk.

The expense of inclosing a preserve is shown by reports¹⁸ regarding the Custer County refuge, South Dakota, comprising 61,440 acres and inclosed by a fence of woven and barbed wire 40 miles long and 8 feet high. The construction of this fence was begun in July, 1913, and completed in November, 1914, and cost \$12,261.05. In the autumn of 1914, 36 head of buffalo were purchased from the Philip herd, Pierre, S. Dak., including 6 bulls, 18 cows, and 12 calves. Early in 1915, 50 elk were obtained from the Yellowstone Park; in 1916, 25; and in 1917, 50 more, making a total of 125 thus obtained. In June, 1921, the total number of buffalo was reported as about 70 and the number of elk about 500. A considerable number of deer are in the inclosure and the preserve has also been stocked with pheasants.

COST OF GAME FARMS.

The cost of maintenance of game farms may be illustrated by the costs of those operated by Illinois, Oregon, and New York.

The Illinois farm, now abandoned, formerly embraced about 534 acres near Auburn, a few miles south of Springfield, and was held under eight leases. The total expense for maintenance during the year ended June 30, 1912, was \$67,142. This total covered the following items: Expenses of the commissioner and purchase of food supplies, \$20,665; purchase of game birds, \$18,267; labor, \$21,662; leases, freight, and express charges, \$6,548. The purchase of game birds included \$2,500 for 1,000 ring-neck pheasant hens, at \$2.50 each; and \$3,915 for 783 pairs of Hungarian partridges, at \$5 per pair. About 15,000 birds were distributed during the year.

In 1914, the Oregon Fish and Game Commission expended \$12,-891.16 on the State game farm. Of this sum \$3,888.42 were spent for salaries and labor, \$4,385 for supplies, \$738.66 for improvements, and \$3,879.08 for game. During the year, 5,686 pheasants, Hungarian partridges, and quail were distributed.

The cost of maintaining the three game farms operated by the Conservation Commission of New York during the year ended June 30, 1919, was \$32,076.14. Of this amount \$13,365.18 were expended for labor, and \$18,710.96 for miscellaneous expenses of maintenance and operation. The number of half-grown birds distributed was 9,206 and the number of eggs 55,400.

SUGGESTIONS FOR MAKING A SURVEY OF GAME RESOURCES.

The information necessary for ascertaining the value of game resources can only be obtained by the adoption of comprehensive plans for collecting it on a broad and practical basis. In the fore-

¹⁸ Rept. Dept. Game and Fish, S. Dak., 1914, p. 12; 1915, p. 7; 1916, p. 19.

going pages reference has been made to some of the experiments of this kind which have been tried in various States. Thus in the New England States provision has been made for appraising and paying for damage done to crops by deer and for ascertaining the number of deer killed in this connection. In the Rocky Mountain States of Montana, Colorado, and Wyoming, and in four of the Canadian Provinces, where guides are commonly employed, they are required to make reports of the amount of game killed by the persons employing them. In several States efforts have been made to obtain statistics of the number of deer killed during the hunting season, and in one or two instances estimates have been made of the total number of deer in a State.

A simple means of obtaining much of the desired information is already provided under the existing system of hunting licenses. State officers report with much detail the number of licenses issued, the amount of money collected for game protection, and the number of arrests made. More attention might be devoted to ascertaining the extent of the stock of game, which is the central point of interest of the whole game-protective machinery of the State. The following modifications of present methods of collecting data would furnish facts of the highest importance:

- (1) Publishing in addition to the number of licenses issued an estimate of the number of persons hunting without license on their own lands or under exemptions allowed by law (an estimate which a State game commission could readily make) would furnish approximately the total number of persons hunting in the State.

- (2) Requiring each big-game hunter to make a return of the results of his activities under his license, as is now done in several States and Canadian Provinces, would give accurate figures of the total number of deer and other big game annually killed.

- (3) Requiring licensees to report the number of game birds actually killed would furnish returns similar to those needed in the case of big game, and while they would be much more difficult to obtain, yet with the necessary legislation and the cooperation of sportsmen's associations, local clubs, and the sportsmen themselves they could be collected, as shown by the results already accomplished.

- (4) Requiring game farms to report the number of birds raised, disposed of for propagation, or sold for market would show the annual results of efforts to domesticate game.

- (5) Estimating the total amount of each kind of game in the State would make it possible, by revising and comparing the estimates from year to year, to tell whether the stock is increasing or whether the total number killed exceeds the annual increase.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 1050

Contribution from the Forest Service
WILLIAM B. GREELEY, Forester



Washington, D. C.

May 12, 1922

THE IDENTIFICATION OF TRUE MAHOGANY,
CERTAIN SO-CALLED MAHOGANIES, AND
SOME COMMON SUBSTITUTES.

By ARTHUR KOEHLER, *Specialist in Wood Structure.*

CONTENTS.

	Page		Page.
"Mahoganies"-----	1	Description of species—Continued.	
Key for the identification of true mahogany and mahogany-like woods-----	2	"African mahogany"-----	9
Description of species—		"Philippine mahogany"-----	10
True mahogany-----	4	"Colombian mahogany"-----	12
Crabwood-----	6	"Liberville mahogany"-----	13
Cedrela-----	7	Birch-----	14
Sapeli-----	8	Red gum-----	15
		"White mahogany"-----	16
		Glossary-----	16

"MAHOGANIES."

Over sixty different species of timber have at one time or another been put on the market under the name of mahogany. Some of these are closely related botanically to true mahogany and others look much like it, while some have only the most general resemblance, and no relationship which under the most liberal interpretation would entitle them to the name.

The woods now most commonly sold as mahogany in this country are true mahogany from tropical America, "African mahogany," and "Philippine mahogany." The Cedrelas (Spanish cedar, etc.) are rarely sold as mahoganies, while crabwood, sapeli, "Colombian mahogany," and "Liberville mahogany" are imported only in small quantities. They are, however, described in this bulletin because of their resemblance to true mahogany. A description of "white mahogany" is also included, for though it has no reddish-brown color and so is not confused with true mahogany by anyone who has seen a few pieces, the name might lead one unfamiliar with it to assume that it is true mahogany of a light color. Birch and red gum are

used principally as acknowledged imitations of mahogany, but sometimes they are used in furniture sold as genuine mahogany.

Of the woods mentioned in this bulletin, true mahogany, crabwood, the Cedrelas, sapeli, and "African mahogany" come from trees which are botanically of the mahogany family (Meliaceæ). They are uniformly distinguished from other woods herein described by the occurrence of a dark reddish-brown gum in the pores. This gum does not completely fill the pores, but occurs as almost black masses here and there. It is seen best with a magnifying glass on longitudinal surfaces, but in many specimens is visible without a lens. Of course, woods of other families may have dark gum in the pores, but none such are commonly substituted for mahogany.¹

KEY FOR THE IDENTIFICATION OF TRUE MAHOGANY AND MAHOGANYLIKE WOODS.²

(Also read carefully the descriptions of these species in the following pages and study the illustrations.)

I. Wood light to dark reddish brown.

- A. Many pores contain more or less of a very dark reddish brown gum visible on longitudinal and end surfaces. Otherwise the pores are open, no tyloses being present. The gum is visible without, but better with a hand lens.

1. Growth rings sharply but not always conspicuously defined.

- AA. Wood without characteristic odor. Growth rings defined by distinct but not always conspicuous lines of soft tissue $\frac{3}{8}$ to $\frac{1}{2}$ inch apart. Pores in each growth ring almost uniform in size.

a. Lines of soft tissue light-colored and conspicuous.

Rays on a freshly cut or split radial surface not much darker than adjacent fibers. *Tangential* surface occasionally but not always figured with very fine bands which run across the grain, due to the rays being in stories. Wood highly variable in weight and light to dark reddish brown in color.

True mahogany-----(*Swietenia* spp.).

b. Lines of soft tissue mostly dark, not conspicuous.

Rays on a freshly cut or split radial surface considerably darker and more reddish than adjacent fibers and usually with a slight purplish tinge. Rays not in stories. Wood moderately hard. Color more of a plain brown than in true mahogany.

Crabwood-----(*Carapa guianensis*).

¹ To one familiar with the examination of wood sections under a high-power microscope, the exceedingly fine pits (as small as in birch) between adjacent vessels and also the septate wood fibers found in *Swietenia*, *Carapa*, *Entandrophragma*, and *Khaya* offer an additional means of distinguishing these members of the mahogany family from others not of the same family. In *Cedrela* the pits are larger, but also very numerous, and the wood fibers are sparingly septate. *Boswellia* (family Burseraceæ) also has septate wood fibers, but the pits in the vessel walls are comparatively large.

² Unless otherwise directed all observations as to structure should be made on the end surface cut smoothly with a very sharp knife, and all observations as to color should be made on freshly cut longitudinal surfaces of the heartwood.

I. Wood light to dark reddish brown—Continued.

A. Many pores contain, etc.—Continued.

1. Growth rings, etc.—Continued.

BB. Wood with characteristic odor of cigar-box cedar.

Growth rings defined by distinct lighter-colored lines and usually, but not always, by rows of larger pores, approaching ring-porous structure as in ash, oak, hickory, and some other hardwoods. Wood light and soft.

Spanish cedar-----(*Cedrela odorata*).

Brazilian cedar-----(*Cedrela braziliensis*).

Toon-----(*Cedrela toona*).

(Odor most pronounced in Spanish cedar.)

2. Growth rings not clearly defined by lighter colored lines or otherwise.

AA. Numerous tangential lines of soft tissue either lighter or darker colored than the adjacent fibers and readily visible without a lens—40 to 50 per inch of radius. Rays usually not in stories and white substance not found in pores. Wood moderately heavy.

Sapeli-----(*Entandrophragma candollei*).

BB. Tangential lines of soft tissue either not present or very rarely an occasional one; however, darker or lighter colored zones without definite boundary, as seen under a hand lens, may be present. Color same as true mahogany, or quite often with a slight purplish tinge when freshly cut. Rays not in stories, or only locally, and white substance not found in pores as in some true mahogany. Wood moderately heavy. "African mahogany"-----(*Khaya* spp.).

B. Pores do not contain a reddish gum.

1. Pores readily visible without a lens on smoothly cut surfaces.

AA. Occasional short or long white tangential lines present, from $\frac{1}{8}$ inch to several inches apart radially, visible without a lens. When viewed with a magnifying glass these lines appear to be made up of a row of small ducts, much smaller than the pores, and completely filled with a white substance. Considerable variation in color. Weight variable, about the same as mahogany.

"Philippine mahogany"-----(*Shorea* spp.).

a. Color moderately light to dark reddish brown, with purplish tinge. Pores comparatively small but visible without a lens. Pinworm holes rare.

Tanguile-----(*Shorea polysperma*).

b. Color dark reddish brown without purplish tinge. Pores slightly larger than in tanguile. Pinworm holes common.

Red lauaan-----(*Shorea negrosensis*).

c. Color very pale reddish brown without purplish tinge. Pores slightly larger than in tanguile. Pinworm holes rare.³

Almon-----(*Shorea eximia*).

³ On account of variations in the structure and color of tanguile, red lauaan, and almon, it is not always possible to distinguish the wood of these species by means of the characteristics given in this key, which is based on typical features.

I. Wood light to dark reddish brown—Continued.

B. Pores do not contain a reddish gum—Continued.

1. Pores readily visible, etc.—Continued.

BB. No white tangential lines consisting of rows of ducts, but numerous very fine continuous lighter-colored lines of soft tissue present, 120 to 175 per inch of radius, barely visible without a magnifying glass. Wood moderately heavy.

"Colombian mahogany"-----(*Cariniana pyriformis*).

CC. No fine light-colored tangential lines present; structure very homogeneous. Color light purplish brown. Wood moderately light and soft.

"Liberville mahogany"-----(*Boswellia klaineana*).

2. Pores not readily visible without a lens.

AA. Pores barely visible without a lens on smoothly cut surfaces in good light; very distinct under a lens. The heartwood is dull reddish brown; the wide sapwood is white. The wood is heavy, usually straight-grained. Sweet birch-----(*Betula lenta*).
Yellow birch-----(*Betula lutea*).

BB. Pores not visible without a lens; very small and uniformly distributed as seen with a lens. The heartwood is reddish brown, often with darker streaks; the wide sapwood is pinkish white (unless blued by stain). The wood is moderately heavy and usually has interlocked grain.

Red gum-----(*Liquidambar styraciflua*).

II. Wood without reddish tinge. Color creamy white to yellowish brown.

Growth rings sharply but not conspicuously defined by white tangential lines or by a slightly darker band of summerwood. Pores of practically uniform size throughout growth ring, barely visible on a smoothly cut end surface, but very distinct as fine grooves on planed longitudinal surfaces; mostly filled with tyloses. Wood with interlocked grain and moderately heavy.

"White mahogany," or primavera-----(*Tabebuia donnell-smithii*).

NOTE.—The sapwood of birch is without reddish tinge, and when taken by itself might be classified under "II" above, although fresh cuts are almost white. For means of distinguishing birch from primavera, see descriptions of these species.

DESCRIPTION OF SPECIES.

TRUE MAHOGANY.⁴

Swietenia mahagoni Jacq.⁵; *Swietenia macrophylla* King.; *Swietenia cirrhata* Blake; *Swietenia humilis* Zucco.; *Swietenia candollei* Pittier.

MAHOGANY FAMILY (MELIACEÆ).

OTHER NAMES.

True mahogany comprises all the species of the botanical genus *Swietenia*, of which five are known at present.⁶

⁴ See U. S. Dept. Agr. Bulletin 474, "True Mahogany," by C. D. Mell. For sale by Superintendent of Documents, Government Printing Office, Washington, D. C. Price, 5 cents.

⁵ The name after a scientific name is usually an abbreviation of the name of the person who first described the species.

⁶ Blake, S. F., "Revision of the True Mahoganies." Journal of the Washington Academy of Sciences, vol. 10, pp. 286-297, f. 1-2.

Mahogany is rarely sold under any other trade name, except that the very light grades are called "bay mahogany" or "bay wood." The Spanish name is "caoba" and in Florida it is called "maderia." *Swietenia cirrhata* is known locally as "venadillo."

Occasionally the name mahogany is modified so as to indicate the country it came from, as Honduras mahogany, Tabasco mahogany, Cuban mahogany, etc.

WHERE GROWN.

True mahogany grows in tropical America from southern Florida and northern Mexico to northern South America, including the West Indies. It does not grow naturally in Brazil or other parts of the world. According to Blake,⁶ *Swietenia mahagoni* grows in the West Indies, Bermuda, and the keys of southern Florida; *S. macrophylla* grows along the eastern coast from the State of Tabasco, Mexico, to Honduras and possibly farther south; *S. humilis* is a native tree of the west coast from Guerrero, Mexico, to northwestern Guatemala; *S. cirrhata* is known to occur naturally in western Mexico from Sinaloa to El Salvador; and *S. candollei* is a native of Venezuela. Of the five species, *Swietenia mahagoni* and *S. macrophylla* are the more common. *Swietenia macrophylla*, which has larger leaves and larger fruit than the West Indian species, grows principally on low lands, and, as a rule, produces softer and lighter colored wood than *S. mahagoni*; however, no distinct differences in the wood by means of which each species can be identified have so far been observed.

PHYSICAL PROPERTIES.

The wood of true mahogany is highly variable in weight; pieces ranging in specific gravity from 0.34 to 0.90, based on oven-dry weight and oven-dry volume, have been found, although very few pieces have a specific gravity greater than 0.70. The wood from southern Florida and Cuba averages heavier than that from Central America.

The color of true mahogany varies from very pale to very dark reddish-brown. The wood is without characteristic odor or taste. True mahogany usually has interlocked grain, which gives the "ribbon" effect to quarter-sawed material. Unlike most other woods with interlocked grain, it does not warp easily.

STRUCTURE.

The pores in true mahogany are plainly visible without a hand lens as minute holes on a smoothly cut end surface (see fig. 1) and as grooves on longitudinal surfaces. They are scattered singly or in short radial rows of 2 to 4. Some of the pores are filled with a dark

⁶ Blake, S. F., "Revision of the True Mahoganies." Journal of the Washington Academy of Sciences, vol. 10, pp. 286-297, f. 1-2.

brown gum, but less plentifully in the light-colored, soft grades than in the darker grades. In heavy grades some pores also contain a whitish substance. (See fig. 1.⁷) These pores differ from the white gum ducts in "Philippine mahogany" in being scattered singly instead of in tangential rows; furthermore, the gum ducts in "Philippine mahogany" are smaller than the sap pores.

The rays on the radial surface are very distinct. On account of the luster of both rays and wood fibers, the rays may appear lighter or darker than the surrounding areas, depending on how the light is reflected. Actually the rays are only slightly, if any, darker than the surrounding fibers, a characteristic which helps to distinguish mahogany from crabwood, in which the rays are considerably darker. In some pieces of mahogany the rays are in rows or stories extending at right angles to the grain—that is, horizontally in the tree—showing up on the tangential surface as striations, or "ripple" marks, across the grain. (See fig. 12.) This condition of the rays being in stories is not always found in true mahogany, but is rarely found in any of the other species herein described, although it is common in a number of other woods not mentioned in this publication.

The growth rings in true mahogany are defined by light-colored concentric lines, in some pieces very close together and in others one half inch or more apart, with considerable variation in the same piece.

CRABWOOD.

(*Carapa guianensis* Aubl.)

MAHOGANY FAMILY (MELIACEÆ).

OTHER NAMES.

This wood is known as "Para mahogany," "Brazilian mahogany," "Demerara mahogany," "British Guiana mahogany," and in South America as "andiroba."

WHERE GROWN.

Crabwood grows in northern South America as far south as the Amazon Valley, although the exact limits of its geographical distribution are not known. It is a common timber tree of British Guiana.

PHYSICAL PROPERTIES.

The wood is moderately heavy and hard, and similar to mahogany, except that such extremes of very light and very heavy grades are not found.

The color is similar to that of true mahogany, except that it is not quite so reddish, but rather more of a plain brown.

⁷ The text figures will be found grouped at the end of this bulletin.

The grain is straighter than in mahogany, but the wood is said to check and warp more easily in seasoning; however, the Forest Service has no authentic information on its seasoning qualities.

STRUCTURE.

The pores are plainly visible on smoothly cut transverse and longitudinal surfaces. They are fairly uniform in size and evenly distributed, and in all respects closely similar to those of true mahogany, but somewhat smaller than in "African mahogany." Hardened masses of dark-brown gum are visible here and there in the pores. These can best be seen with a hand lens on longitudinal surfaces. No whitish deposits in the pores of this wood have been noticed by the author, although Dixon⁸ reports their occurrence. (See fig. 2.)

The rays are very fine on cross-section, but quite conspicuous on radial surfaces, owing to the fact that they contain reddish coloring matter. (See fig. 13.) This reddish color of the rays is one of the chief means of distinguishing crabwood from true mahogany, although the rays in mahogany may appear darker if the light is reflected in a certain manner. All "Philippine mahogany" and occasional pieces of "African mahogany" may also have reddish rays, but can be distinguished from crabwood by other means. (See key.)

The growth rings, which are very irregular in width, are faintly defined by somewhat lighter colored lines of soft tissue similar to but much less conspicuous than those in mahogany.

CEDRELA.

Spanish Cedar (*Cedrela odorata* L.); Brazilian Cedar (*Cedrela braziliensis* Juss.); Toon (*Cedrela toona* Roxb. or *Toona ciliata* Roem. or *Toona toona* Wight.).

MAHOGANY FAMILY (MELIACEÆ).

OTHER NAMES.

Spanish cedar⁹ is also commonly known as "cigar-box cedar."

Brazilian cedar⁹ is known in South America as "cedro."

Toon has been marketed as "Indian mahogany" and "toona mahogany."

The Spanish and Brazilian cedars are rarely sold as mahogany, but because of their resemblance to the light grades of true mahogany their description is included here.

⁸ Dixon, H. H., "Mahogany, and the Recognition of Some of the Different Kinds by Their Microscopic Characteristics." Scientific Proceedings of the Royal Dublin Society, Vol. XV (N. S.), No. 34, Dec., 1918.

⁹ These species are not true cedars. They belong to the hardwood class, that is, trees with broad leaves, but were probably given the name of cedar because of the aromatic odor of the wood.

WHERE GROWN.

The true Spanish cedar (*Cedrela odorata* L.) is not definitely known outside of the West Indies and French Guiana.

Brazilian cedar grows in Brazil and northern Argentina. A number of minor species of *Cedrela* are also found in Mexico, Central America, and South America.

Toon is a native of India, Java, and Australia, and is shipped to the United States in comparatively small quantities. A similar species, calantas (*Toona calantas* Merr. and Rolfe), is of commercial importance in the Philippine Islands.

PHYSICAL PROPERTIES.

The color of these woods is very much like that of true mahogany. In weight they are lighter than the average mahogany. They have a distinct, pleasant odor, most pronounced in Spanish cedar. The grain of the wood is not interlocked so much as in mahogany.

STRUCTURE.

The pores of the *Cedrelas* are plainly visible with the unaided eye. (See fig. 3.) Some of the pores are partly filled with a dark reddish-brown gum, a characteristic of the mahogany family. As a rule, but not always, the pores are slightly larger at the beginning of each growth ring, making the wood "ring-porous." The growth rings are also defined by a light-colored line of soft tissue, as in true mahogany. This line is not so conspicuous in toon as in the two species from the American Tropics.

The rays are very fine, being barely visible with the unaided eye on a smoothly cut end surface. On radial surfaces they are very lustrous and appear lighter or darker than the surrounding fibers, depending on how they reflect the light. These rays are never storied, as in some pieces of mahogany.

SAPELI.¹⁰

Entandrophragma candollei Harms.

MAHOGANY FAMILY (MELIACEÆ).

OTHER NAME.

"African mahogany."

Other species of *Entandrophragma*, with similar characteristics, may also be included with sapeli. *Entandrophragma candollei* is known as "unscented mahogany," and *E. utilis* as "scented mahogany."¹¹

¹⁰ Also spelled "sapele;" in either case pronounced sap'-el-e.

¹¹ Unwin, A. Harold, "West African Forests and Forestry." T. Fisher Unwin, publisher, London, 1920.

WHERE GROWN.

Countries bordering on the Gulf of Guinea, west coast of Africa.

PHYSICAL PROPERTIES.

The wood is considerably heavier than that of the Khayas. The grain may be very much interlocked, but no information as to whether the wood warps easily is available. No pronounced odor or taste is present in the wood, although a slight odor, faintly resembling that of Spanish cedar, is noticeable in some pieces.

STRUCTURE.

The pores are visible without magnification on smoothly cut end and longitudinal surfaces. They are fairly uniform in size, evenly distributed, singly or often in twos, and occasionally in threes. As in other species of the mahogany family, the pores contain more or less of a dark reddish-brown gum.

The chief characteristic of sapeli is the presence of numerous tangential lines of soft tissue seen on a smoothly cut end section of the wood. (See fig. 4.) These lines are usually darker, but may be lighter, than the other portion of the wood and average 40 to 50 to the radial inch. The constant closeness of these lines eliminates the possibility of mistaking them for lines limiting growth rings, as in true mahogany. Seasonal growth rings are not clearly defined. According to Record,¹² the rays are more or less storied as seen on the tangential faces, but this was not the case in the specimens available to the writer.

"AFRICAN MAHOGANY."

(*Khaya* spp.)

MAHOGANY FAMILY (MELIACEÆ).

OTHER NAMES.

Several species of the genus *Khaya* are marketed as African mahogany.¹³ Probably the most common one is *Khaya senegalensis* A. Juss. Other names applied to these species are "Senegal mahogany," "Gambia mahogany," "Benin mahogany," and "Gaboon mahogany," indicating the regions from which the species are obtained.

Other species, as sapeli, and some not of the mahogany family, are occasionally called "African mahogany," but very little wood of these species is brought into the United States.

¹² Record, S. J., "Mahogany and Some of Its Substitutes." *Journal of Forestry*, Vol. XVII, No. 1, Jan., 1919.

¹³ For detailed information concerning the various species of *Khaya* see Unwin, Harold A., "West African Forests and Forestry."

WHERE GROWN.

West coast of Africa and inland along a belt from 15° north to 20° south of the Equator, and found occasionally in Uganda and Mozambique on the east coast.

PHYSICAL PROPERTIES.

African mahogany is similar to true mahogany in its properties, except that it does not show such extremes of density and color. Occasional boards have a purplish tinge mixed with the usual reddish-brown color.

Interlocked grain is usually present, but, as in true mahogany, is not associated with excessive warping.

STRUCTURE.

The pores are plainly visible without a lens; in fact, they are slightly larger than in true mahogany, giving the wood a coarser texture. They are fairly uniform in size and evenly distributed. (See fig. 5.) Abundant dark reddish-brown gum is found in most of the pores.

No distinct growth rings are present. Lighter and darker concentric zones are often found, but without a sharp line of demarcation. The absence of the fine tangential lines limiting growth rings in true mahogany of tropical America is the chief feature of distinction between these two woods. The author has noticed one or two such lines in certain pieces of "African mahogany," but not many, as is usual in true mahogany. Care must be taken not to mistake knife marks for such fine lines.

The rays are barely visible without a lens on a smoothly cut end surface, but are very plain and lustrous on radial surfaces. They are never conspicuously storied on the tangential faces, as in true mahogany, although they may be in irregular stories locally.

"PHILIPPINE MAHOGANY."¹⁴

Tanguile¹⁵ (*Shorea polysperma* Merr.); Red lauaan¹⁶ (*Shorea negrosensis* Foxw.); Almon (*Shorea eximia* Scheff.).

LAUAAN OR DIPTEROCARP FAMILY (DIPTEROCARPACEÆ).

OTHER NAMES.

Tanguile is also known as "Bataan mahogany" and "tanguile mahogany." The heavier grades of red lauaan are substituted for tan-

¹⁴ See Philippine Bureau of Forestry Bulletin 14, "Commercial Woods of the Philippines: Their Preparation and Uses," by E. E. Schneider. Bureau of Printing, Manila, P. I. Price, \$1.

¹⁵ Also spelled "tangil." Pronounced tang-he'-le.

¹⁶ Pronounced lau-ah-an'.

guile on the Manila market. Almon has no other common names except in the native dialect.

Tanguile and red lauaan constitute the bulk of so-called "Philippine mahogany" sent to the United States. Almon is included occasionally. Rarely, other species of the Dipterocarp family may be included, especially white lauaan (*Pentacme contorta* Merr. and Rolfe) and bagtican (*Parashorea malaanonan* (Blanco) Merr.). When tanguile is desired, *genuine tanguile* should be specified.

WHERE GROWN.

Philippine Islands.

PHYSICAL PROPERTIES.

Tanguile is "soft to moderately hard; light to moderately heavy, specific gravity 0.469 to 0.509 (Gardner);¹⁷ heartwood pale red to dark reddish-brown; grain distinctly crossed, producing a broad, conspicuous ribbon when quarter-sawed; seasons well, but may warp if not carefully stacked; easy to work."¹⁸

Red lauaan is "soft to moderately hard; light to moderately heavy, specific gravity 0.406 (Gardner); heartwood light red to dark reddish brown; grain distinctly crossed, forming a conspicuous ribbon when quarter-sawed; texture rather coarse; seasons well, splitting and warping very little; easy to work."¹⁸

Almon is "soft; light, specific gravity 4.464 (Gardner); heartwood very pale red; texture rather coarse; grain somewhat crossed, making a narrow distinct ribbon when quarter-sawed, small but distinct silver grain; seasons well, checking and warping very little; very easy to work."¹⁸

Tanguile, in general, is slightly heavier, harder, stronger, and finer-grained than either red lauaan or almon.

STRUCTURE.

The pores are very distinct on smoothly cut transverse and longitudinal surfaces. They are fairly uniform in size in each species, but average slightly smaller in tanguile than in red lauaan and almon. They are evenly distributed, singly or occasionally by twos. The pores are open for the most part, but occasionally contain tyloses. Reddish-brown gum is never found in the pores.

White tangential lines varying in length from very short to the full thickness of a board are usually common on the cross-section (see

¹⁷ The moisture percentage and the volume (oven-dry or otherwise) on which this specific gravity is based are not given, but undoubtedly the basis of computation was the same as that used in computing the specific gravities of red lauaan and almon quoted in the succeeding paragraphs. Forest Products Laboratory determinations show an average specific gravity for tanguile based on the oven-dry weight and oven-dry volume of 0.57.

¹⁸ Philippine Bureau of Forestry Bulletin 14, pp. 168-171.

fig. 6), but may be absent for areas of several square inches. Under a magnifying glass it can be seen that these white lines are made up of rows of ducts (smaller than the pores) containing a white gum, differing in this respect and in not being continuous from the light-colored lines found in true mahogany. These tangential rows of white gum ducts are found in no other species sold as mahogany, unless it be in other species of the Dipterocarp family which may occasionally be included in shipments of "Philippine mahogany."

Short lines of lighter colored tissue extending for a short distance tangentially from the pores may occasionally be seen with a lens on smoothly cut end surfaces. It is not necessary to look for these, however, in distinguishing "Philippine mahogany" from other species herein described.

The rays are not visible without lens on an end section, but are very conspicuous on radial surfaces because of their reddish color.

No well-defined growth rings are present, although the rows of gum ducts when long might be mistaken for the termination of seasonal layers.

"COLOMBIAN MAHOGANY,"²⁰

(*Cariniana pyriformis* Miers.)

MONKEY-POD FAMILY (LECYTHIDACEÆ.)

OTHER NAMES.

Cariniana, albarco (Colombia).

WHERE GROWN.

Colombia, South America.

PHYSICAL PROPERTIES.

The wood has about the same weight and color as moderately heavy mahogany, except that a slight purplish tinge is usually present. It has more or less interlocked grain, but is said not to give any trouble by warping when properly seasoned.

STRUCTURE.

The pores are visible without a lens on smoothly cut end and longitudinal surfaces. They are fairly uniform in size, and evenly scattered, singly or occasionally by twos. They do not contain brownish gum, as do those in true mahogany, but contain some tyloses. The growth rings are very faintly defined by a slight difference in the size of the pores.

²⁰ See Forest Service Circular 185, "Colombian Mahogany," by Geo. B. Sudworth and C. D. Mell. Government Printing Office, Washington, D. C. Price, 5 cents.

A striking characteristic of the wood is the presence of very numerous, fine, lighter colored, tangential lines of soft tissue, barely visible without a lens. These lines are fairly evenly spaced and average from 120 to 175 per inch of radius. (See fig. 7.) Similar lines, but wider apart, are found in sapeli, and the presence in "Colombian mahogany" of tyloses instead of gum is an additional aid in distinguishing the two species.

The rays are not distinctly visible on cross sections, but on radial surfaces are very distinct because of their reddish-brown color.

"LIBERVILLE MAHOGANY."

(*Boswellia klainiana* Pierre.)

MYRRH FAMILY (BURSERACEÆ).

OTHER NAMES.

Gaboon mahogany; okume; okoumie; African cedar.

WHERE GROWN.

French Kongo and adjacent territory of Africa.

PHYSICAL PROPERTIES.

The wood is lighter and softer than the average genuine mahogany, although it is firm enough to be used for furniture and similar articles. It is pale pinkish-brown or pale flesh-colored with a faint lavender tinge. Dressed surfaces appear lustrous. The wood is without characteristic odor or taste.

The grain runs straighter than in mahogany, and hence the "ribbon" effect is not so pronounced in quarter-sawed lumber.

STRUCTURE.

The pores are very distinct to the unaided eye, being of about the same size as those in true mahogany. They are scattered singly, or occasionally several in short radial rows. The pores are empty, except for occasional tyloses.

Tangential lines of light-colored tissue are absent, although poorly defined tangential zones of darker and lighter wood may occasionally be present. (See fig. 8.)

The rays are very fine, not visible on a cross-section without a hand lens.²¹ On radial surfaces they are distinct but comparatively small, and not much darker than the surrounding wood.

²¹ "Liberville mahogany" and "Colombian mahogany" are the only species herein described in which the rays are characteristically 2 (occasionally 1 or 3) cells wide, as seen with a high-power microscope on the tangential section. In all the other species the larger rays are 4 or more cells wide, except in some pieces of red gum in which the rays are mostly 2 or 3 cells wide.

BIRCH.

Sweet birch (*Betula lenta* Linn.) ; yellow birch (*Betula lutea* Michx. f.).

BIRCH FAMILY (BETULACEÆ).

OTHER NAMES.

Sweet birch is also known as cherry birch, black birch, and mahogany birch.

Yellow birch is also known as gray birch, silver birch, and swamp birch.

The heartwood of both species is usually sold as "red birch" and the sapwood as "yellow birch."

Other species of birch are rarely cut into lumber.

WHERE GROWN.

Sweet birch grows within an area that extends from Newfoundland to eastern Iowa, and south to northern Florida. It is of commercial importance, principally in the East, from New York State south along the Appalachian Mountains, although it is cut as far west as Wisconsin.

Yellow birch occurs from Newfoundland to northern Minnesota, and through the northern States to eastern Tennessee, North Carolina, and Delaware. It is most abundant and reaches its largest size in northern New England and New York and in northern Michigan and Wisconsin.

PHYSICAL PROPERTIES.

Although sweet birch averages slightly heavier and harder than yellow birch, the difference is so little that usually no distinction is made between the two species when used in the form of lumber. Both species are hard, heavy, and strong in bending.

Birch has somewhat of a tendency to warp, but not so much as red gum and other species with decidedly interlocked grain.

The heartwood is reddish brown; the sapwood, which is often wide, is practically white. Much sapwood is used in the manufacture of furniture with a mahogany finish. It is difficult to hide its identity since any wear or fracture is likely to disclose the white wood underneath the finish.

STRUCTURE.

The pores in birch are of such size that they can barely be seen in good light without a lens on the smoothly cut end surface. On the longitudinal dressed surface they appear as very fine grooves. They are almost uniform in size throughout each annual ring, although occasionally they are noticeably smaller toward the end of each year's growth. (See fig. 9.) The annual rings are defined by fine lines.

The rays are not distinctly visible without a lens on the cross-section. On radial surfaces they appear as fine reddish-brown "flakes."

RED GUM.

(*Liquidambar styraciflua* Linn.)

WITCH HAZEL FAMILY (HAMAMELIDACEÆ).

OTHER NAMES.

Sweet gum; star-leaved gum; hazel wood; satin walnut (Europe); sap gum (sapwood only).

WHERE GROWN.

In the United States south of a line from Connecticut through southern Illinois and Eastern Texas, except in southern Florida. It is very uncommon in the Southern Appalachian Mountains and the surrounding highlands, but is found on the mountains of Central and Southern Mexico and on the highlands of Guatemala. Most abundant commercially in the bottom lands of the lower Mississippi Valley.

PHYSICAL PROPERTIES.

The wood is moderately heavy and moderately hard. It usually has interlocked grain, which causes it to warp, especially when plain sawed, unless properly seasoned.

The heartwood is reddish-brown, varying more or less in shade. It often contains darker streaks which add to its beauty. The sapwood is pinkish white unless blued by stain. It is often wide and is sold separately as "sap gum."

STRUCTURE.

The pores are so small that they can not be seen without a good magnifying glass. (See fig. 10.) This feature distinguishes red gum from mahogany and mahogany-like woods. The pores are of uniform size and distribution throughout each annual ring, making it difficult to differentiate each year's growth, although on careful examination with a lens a fine line can be seen separating the annual growth layers.

The rays are fairly distinct, but not at all conspicuous without a lens on either an end or a radial surface, since they are relatively small and of about the same color as the surrounding wood.

Since the annual rings, pores, or rays do not stand out clearly, red gum has no characteristic figure except for the darker streaks in some grades.

"WHITE MAHOGANY."*(Tabebuia donnell-smithii* Rose.)

TRUMPET-CREEPER OR CATALPA FAMILY (BIGNONIACEÆ).

OTHER NAMES.

Primavera. The names "jenicero" or "genesero" have also been applied to this wood, but these names are also used for an entirely different Mexican species, namely, guanacaste (*Enterolobium cyclocarpum*).

WHERE GROWN.

Western coast of Mexico and southward to Guatemala.

PHYSICAL PROPERTIES.

The wood is moderately heavy and hard, works well, and is said to give little trouble by warping. It is creamy white to yellowish-brown in color. The grain is interlocked, and the pores are of about the same size as in true mahogany, so that the figure produced, especially when finished with a mahogany stain, is similar to that of true mahogany.

STRUCTURE.

The pores are plainly visible on longitudinal surfaces as grooves, and can be seen on smoothly cut end surfaces as minute openings. They are arranged so as to form diagonal or wavy tangential rows, especially in the outer portion of each growth ring as seen on the cross-section. (See fig. 11.) Tyloses are very common in the pores. Fine tangential lines, often accompanied by a darker layer of summerwood, mark the limits of the growth rings. In some pieces the pores are also slightly larger at the beginning of each growth ring, making the rings more conspicuous.

The rays are barely visible on cross-section and inconspicuous on radial surfaces. On tangential faces they may or may not appear storied. When storied they never produce conspicuous "ripple" marks, as in true mahogany.

GLOSSARY.

Density.—Amount of wood substance, equivalent to oven-dry weight.

Ducts, or gum ducts.—Special ducts for storing or conveying gum. Found only in a few species of hardwoods; usually smaller and less numerous than the pores for conducting sap.

Family.—Botanically speaking, a group of plants having certain fundamental resemblances, especially in the flowers and fruit, yet differing more or less in this and other respects. For example,

apple, pear, and quince belong to one family, and walnut and hickory to another family.

Fibers.—The comparatively long thin cells usually comprising the bulk of the wood, but too small to be seen except with a high-powered microscope. Distinguished from the pores in the hardwoods, which are larger but less numerous.

Growth rings.—The well-defined layers of wood put on each season usually, but not necessarily, limited to one each year.

Gum.—A white or dark deposit, partly or wholly filling the sap pores or the gum ducts of certain woods.

Interlocked grain.—Fibers slanting around the tree in one direction for a number of years and then reversing to the other direction, and later reversing again, and so on, producing a “ribbon” effect on quarter-sawed lumber.

Light-colored lines.—Very thin light-colored lines extending circumferentially on the cross-section. These may mark the end of each growth ring, or many may be formed each season, as in sapeli and “Colombian mahogany.” Composed of soft tissue technically known as parenchyma.

Longitudinal surfaces.—Either radial or tangential surfaces, as distinguished from cross-section, or end grain.

Pores.—Larger cells with open ends set one above the other, and used for conducting sap, as distinguished from the smaller wood fibers with closed ends used to give strength to the tree trunk. (True pores are not found in the coniferous woods, in which the fibers serve the combined purpose of conducting sap and giving strength to the tree.)

Radial.—Along the radius.

Radial surface.—A longitudinal surface cut approximately along the radius of the log, that is, from the bark toward the center; equivalent of edge grain or quarter-sawed surface.

Rays.—Rows of cells extending horizontally in a tree from the bank inwardly at right angles to the grain. Visible on strictly radial surfaces of all woods; very conspicuous in quartered oak. (See fig. 13.) On end surfaces they may be seen with a lens, or occasionally without, as fine radial lines crossing the growth rings.

Ring-porous.—Having the pores at the beginning of each growth ring comparatively large, with more or less abrupt decrease in size toward the outer portion of the growth ring.

Ripple marks.—Fine transverse markings uniformly spaced on the tangential faces of wood. (See fig. 12.)

Soft tissue.—Thin-walled cells, often in rows, usually producing lighter-colored lines when cut across the grain, used to store food. Technically called parenchyma.

Specific gravity.—The ratio of the weight of a piece of wood (or other substance), usually oven-dry, to the weight of an equal volume of water, with the latter considered as 1. (For most woods the specific gravity is less than 1, because they are lighter than water, which weighs nearly 62.5 pounds per cubic foot.)

Storied rays.—Rays arranged in horizontal layers or stories in the tree, producing “ripple” marks on tangential faces. (See fig. 12.)

Summerwood.—The outer, often darker and harder portion of each annual ring.

Tangential.—Along a tangent, or at right angles to the radius.

Tangential surface.—A longitudinal surface cut approximately at right angles to the rays, equivalent to flat grain or plain-sawed surface.

Tyloses.—Glistening, froth-like ingrowths in the pores of the heartwood, closing them up more or less.

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
10 CENTS PER COPY

△

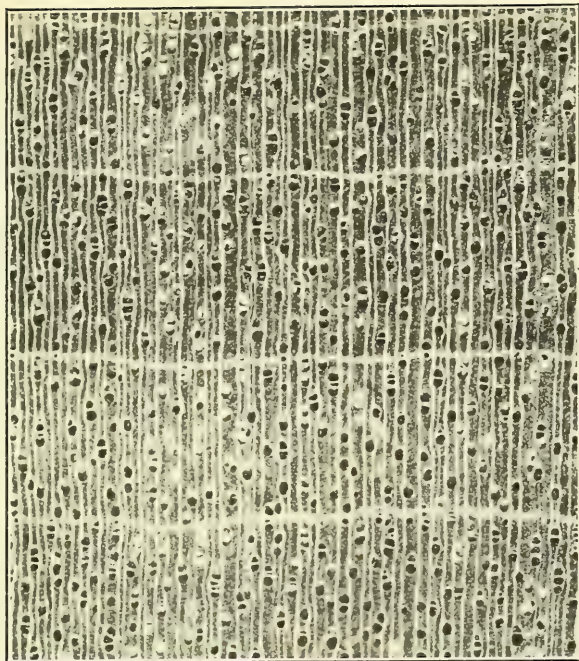


FIG. 1.—TRUE MAHOGANY. END GRAIN MAGNIFIED 7.5 DIAMETERS.

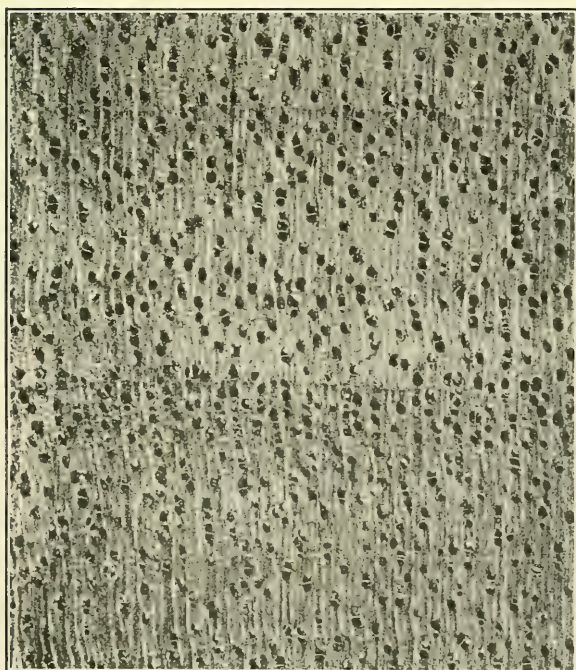


FIG. 2.—CRABWOOD. END GRAIN MAGNIFIED 7.5 DIAMETERS.

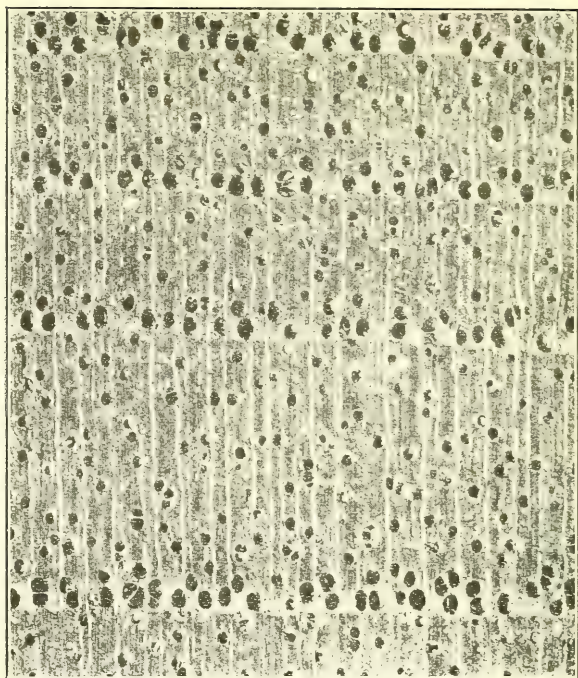


FIG. 3.—SPANISH CEDAR. END GRAIN MAGNIFIED 7.5 DIAMETERS.

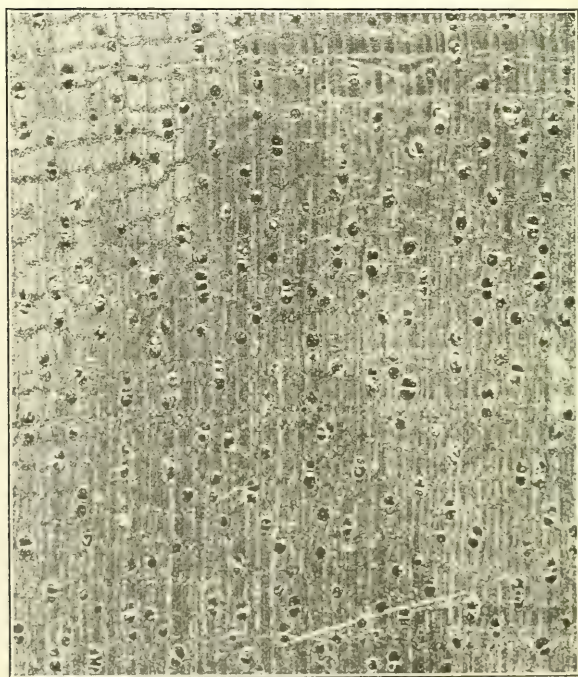


FIG. 4.—SAPELI. END GRAIN MAGNIFIED 7.5 DIAMETERS.

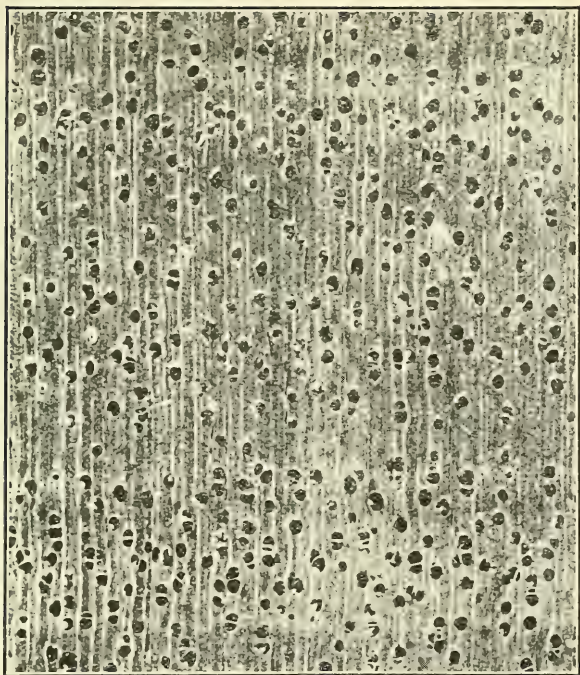


FIG. 5.—"AFRICAN MAHOGANY." END GRAIN
MAGNIFIED 7.5 DIAMETERS.

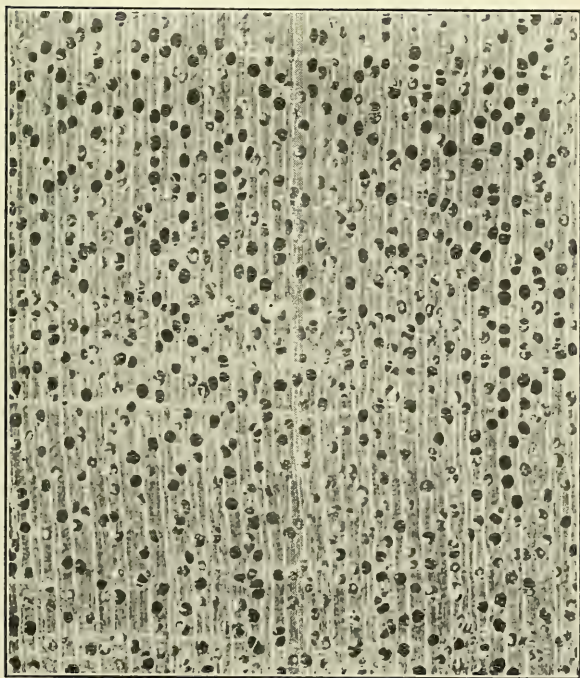


FIG. 6.—"PHILIPPINE MAHOGANY." END GRAIN
MAGNIFIED 7.5 DIAMETERS.

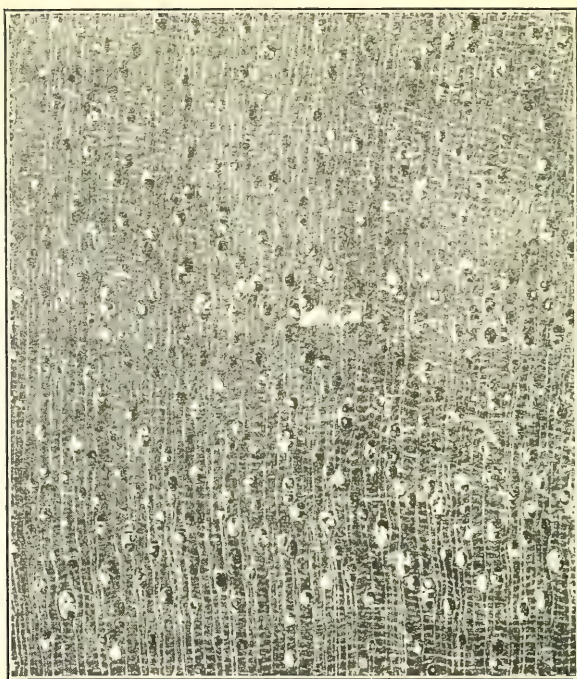


FIG. 7.—"COLOMBIAN MAHOGANY." END GRAIN
MAGNIFIED 7.5 DIAMETERS.

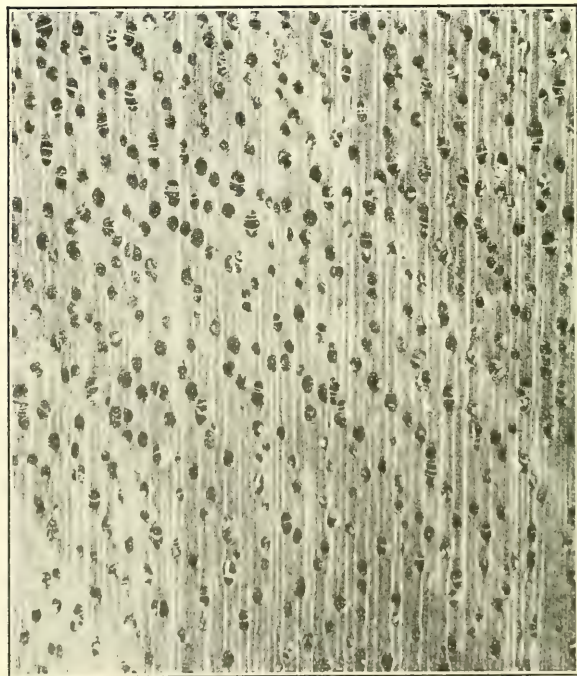


FIG. 8.—"LIBERVILLE MAHOGANY." END GRAIN
MAGNIFIED 7.5 DIAMETERS.

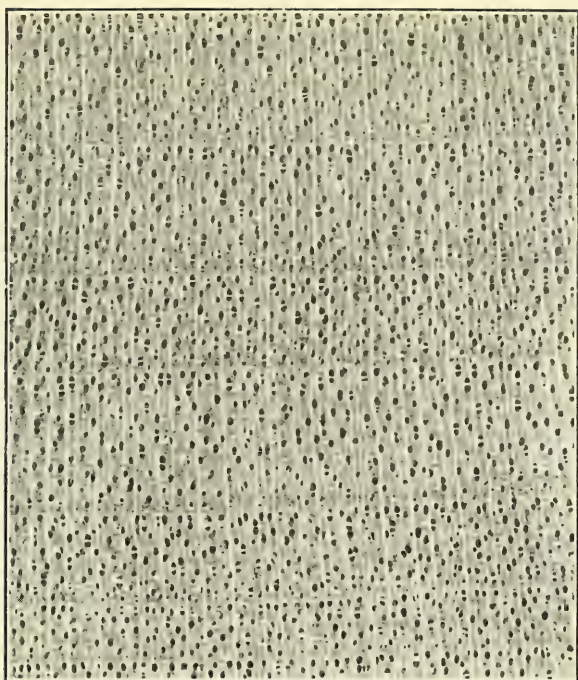


FIG. 9.—YELLOW BIRCH. END GRAIN MAGNIFIED
7.5 DIAMETERS.



FIG. 10.—RED GUM. END GRAIN MAGNIFIED
7.5 DIAMETERS.

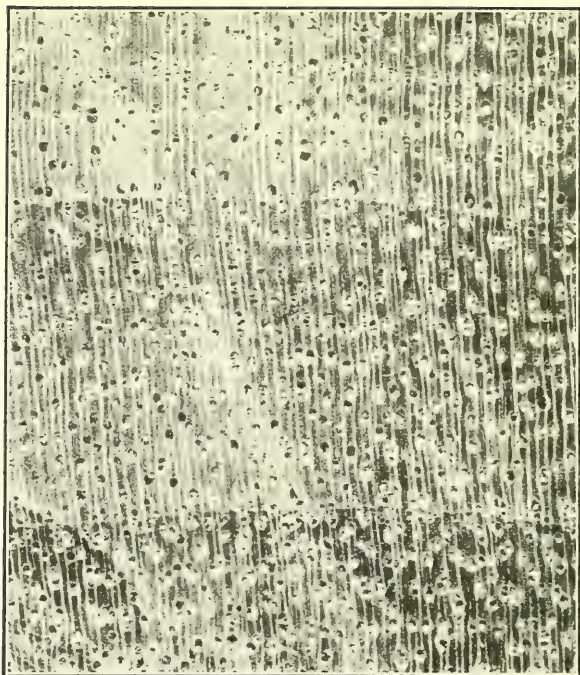


FIG. 11.—"WHITE MAHOGANY." END GRAIN
MAGNIFIED 7.5 DIAMETERS.

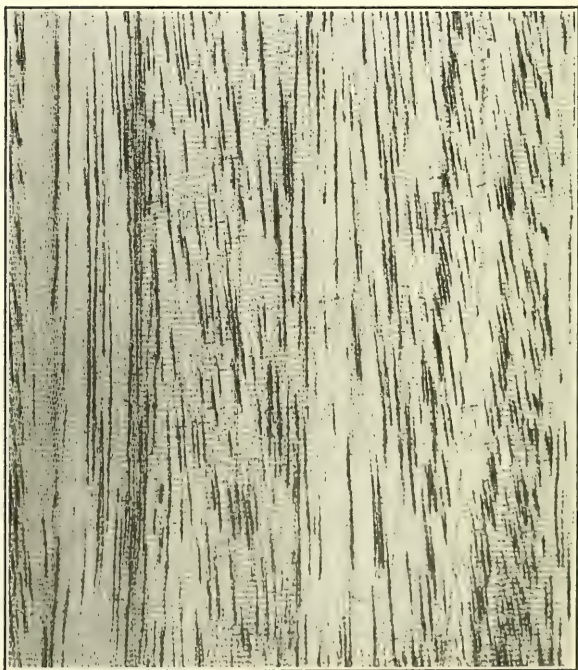


FIG. 12.—TANGENTIAL SURFACE OF TRUE MAHOGANY
SHOWING THE RAYS MORE OR LESS IN HORIZONTAL
ROWS OR STORIES.

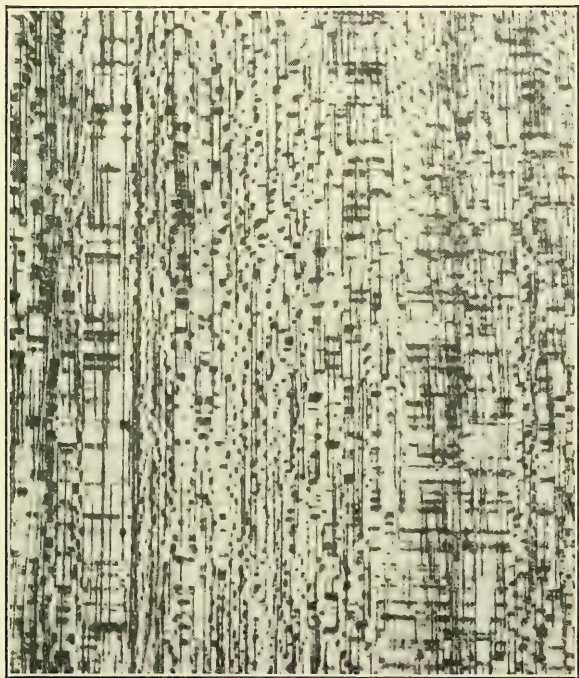


FIG. 13.—RADIAL SURFACE OF CRABWOOD SHOWING
DARK RAYS.





UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 1026

Contribution from the Bureau of Public Roads
THOMAS H. MacDONALD, Chief

Washington, D. C.

May 16, 1922

IRRIGATION IN NORTHERN COLORADO

By

ROBERT G. HEMPHILL, Irrigation Engineer.

CONTENTS

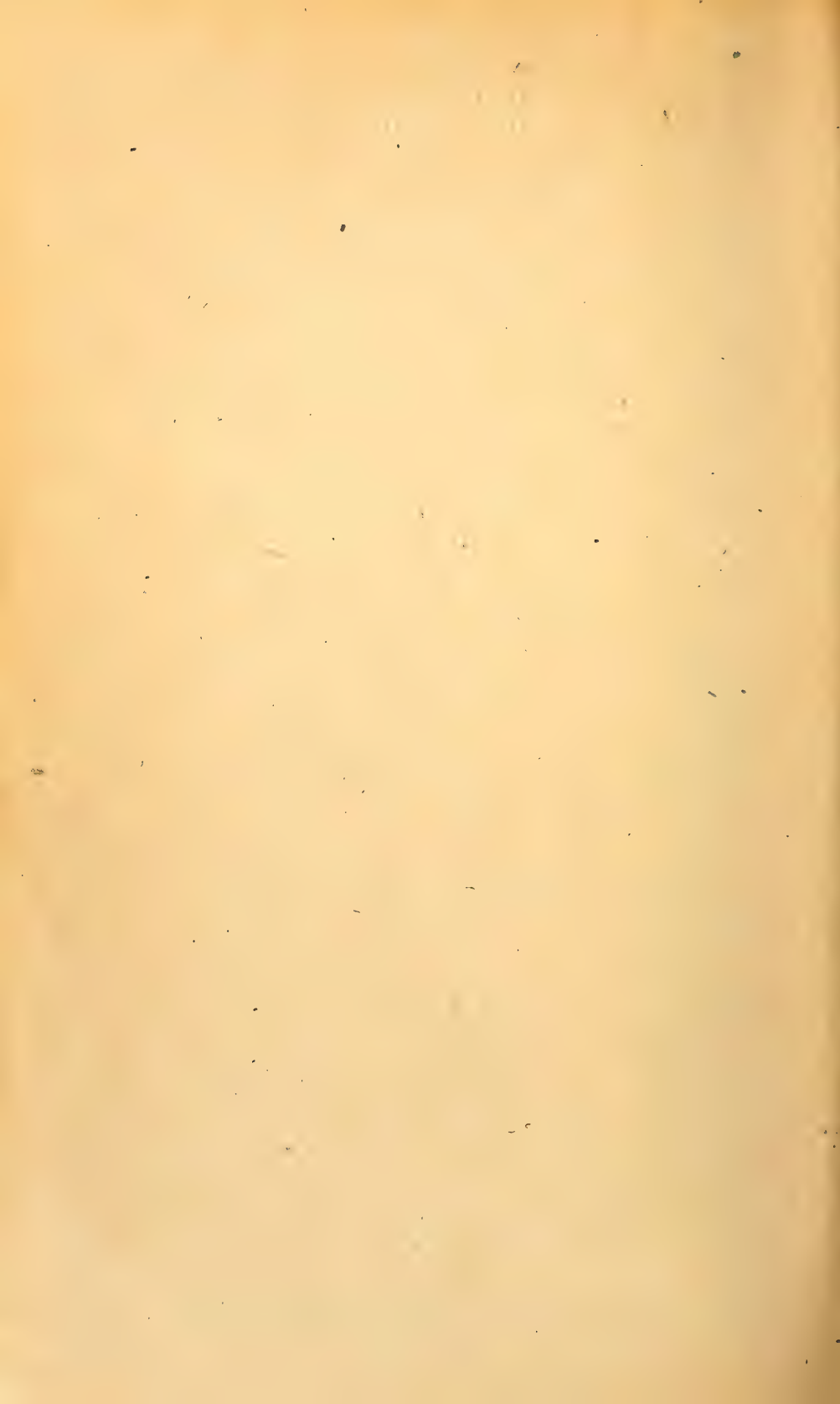
	Page		Page
Introduction	1	Water Rights	13
Cache la Poudre Valley	2	Distribution from River	19
Meteorology	3	Duty of the River	24
Soils	5	Canal Systems	26
Water Resources	6	Gross Duty for Canals	42
Seepage Return	10	Farm Irrigation	51
Drainage Conditions	12	Reservoirs	69
Exchange of Water	12	Summary and Conclusions	79

(Based on data gathered under cooperative agreement between the
Bureau of Public Roads of the United States Department of Agriculture
and the Colorado Agricultural Experiment Station)



WASHINGTON
GOVERNMENT PRINTING OFFICE

1922



UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 1027

Contribution from the Bureau of Chemistry
W. G. CAMPBELL, Acting Chief

Washington, D. C.

April 17, 1922

POISONOUS METALS ON SPRAYED
FRUITS AND VEGETABLES

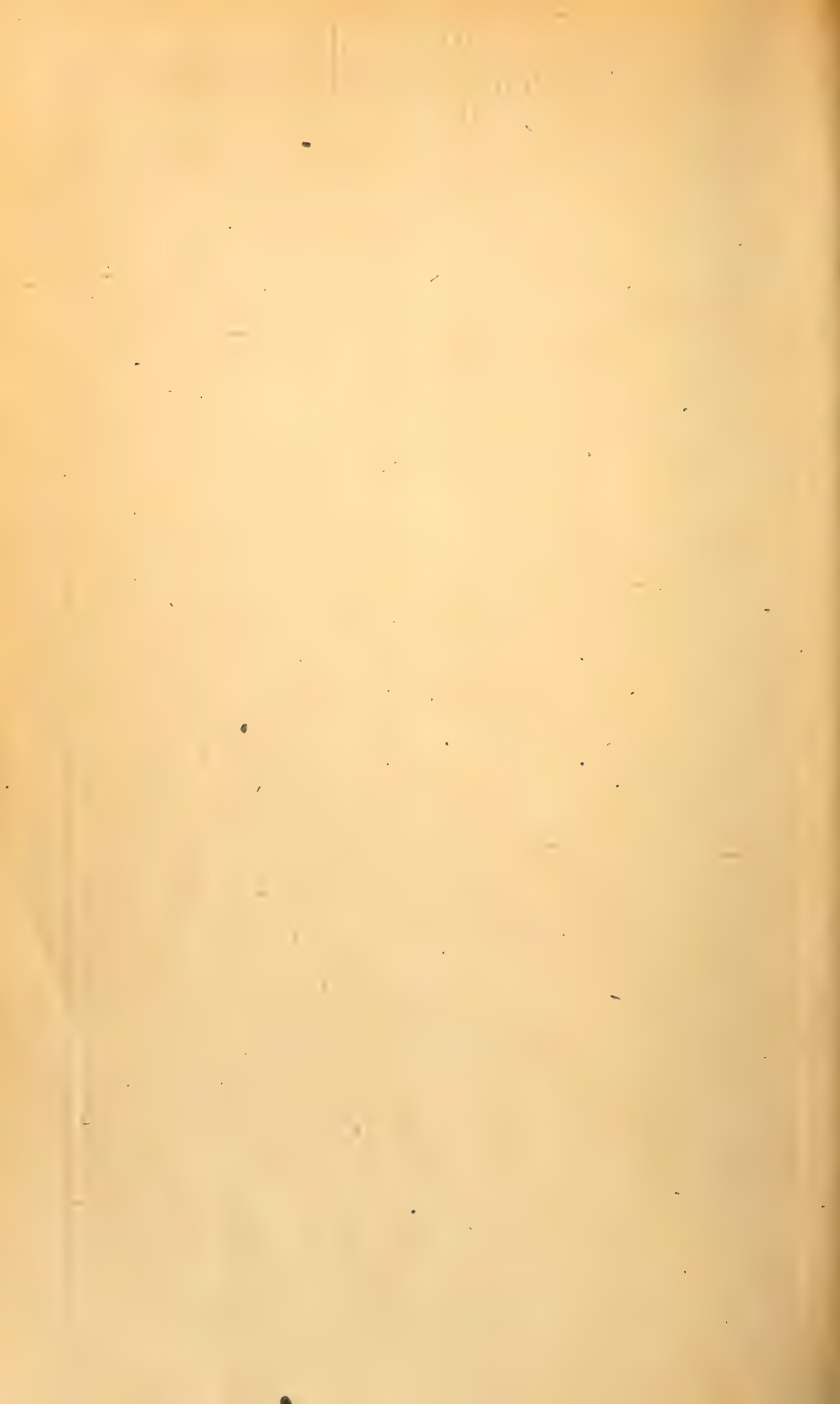
BY

W. D. LYNCH, Assistant Chemist, C. C. McDONNELL, Chief, Insecticide and Fungicide Laboratory, and J. K. HAYWOOD, Chief, Miscellaneous Division, Bureau of Chemistry; A. L. QUAINANCE, Entomologist in Charge, Fruit Investigations, Bureau of Entomology; and M. B. WAITE, Pathologist in Charge, Fruit-Disease Investigations, Bureau of Plant Industry

CONTENTS

	Page
Purpose of Investigation	1
Results of Previous Investigations	1
Experimental Work	16
Results of Experimental Work	18
Summary	58
Literature Cited	58





UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 1031

Contribution from the Forest Service
WILLIAM B. GREELEY, Forester

Washington, D. C.

May 15, 1922

RANGE AND CATTLE MANAGEMENT DURING DROUGHT

By

JAMES T. JARDINE, Inspector of Grazing, and CLARENCE
L. FORSLING, Grazing Examiner

CONTENTS

	Page		Page
The problem of drought and cattle produc- tion.	1	Adjustments necessary, etc.—Continued.	
Jornada Range Reserve	4	Breeding herd should be limited to grazing capacity of range during drought	43
Types of vegetation	5	Surplus stock should vary with range forage production and with the market	46
Use prior to reservation	10	Range management to obtain maxi- mum forage production and proper use	49
Recurrence of drought	11	Improvements necessary to meet increase in cost of cattle production.	53
Variation in forage production	18	Improvements in grade of stock	54
Variation due to drought	19	Increasing calf crop	58
Variation due to grazing	25	Decreasing losses of cattle.	65
Forage production conclusions	33	Increasing growth of young stock	77
Grazing capacity	34	Summary	79
Yearlong or winter range	35	List of publications relating to this subject	82
Summer range	40		
Adjustments necessary in cattle manage- ment	41		
Southern New Mexico a cattle-breed- ing section	42		



WASHINGTON
GOVERNMENT PRINTING OFFICE

1922

UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 1032

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C.

April 25, 1922

THE BLACKHEAD FIREWORM
OF CRANBERRY
ON THE PACIFIC COAST

BY

H. K. PLANK

Scientific Assistant, Fruit Insect Investigations

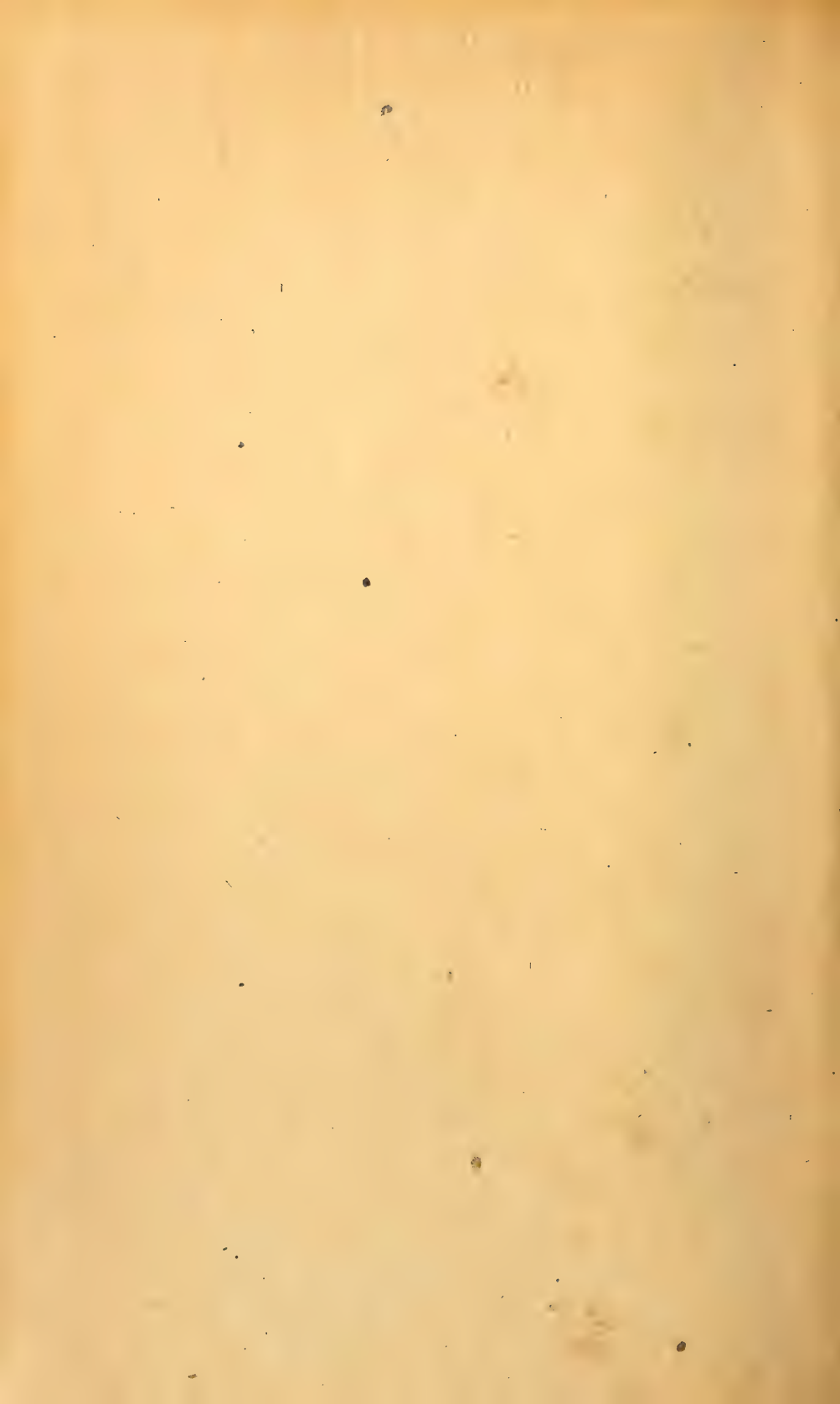
In cooperation with the Washington Agricultural Experiment Station, with
Technical Description by CARL HEINRICH, Bureau of Entomology

CONTENTS

	Page		Page
Introduction	1	Seasonal History	19
Introduction of the Blackhead Fireworm into the Northwest	4	Natural Enemies	20
Distribution	5	Control Experiments	22
Food Plants	5	Recommendations for Control	34
Destructiveness	5	Summary and Conclusions	37
Number of Generations	6	Systematic Description of <i>Rhopobota</i> <i>naevana</i> Hübner	42
Description of Stages and Habits	7	Explanation of Plates	45



WASHINGTON
GOVERNMENT PRINTING OFFICE
1922



UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 1034

Contribution from the Office of Farm Management and Farm Economics
G. W. FORSTER, Acting Chief

Washington, D. C.

PROFESSIONAL PAPER

June 28, 1922

FARM MANAGEMENT AND
FARM ORGANIZATION IN SUMTER COUNTY
GEORGIA

AN ANALYSIS OF THE BUSINESS OF 534
FARMS IN 1913, AND 550 FARMS IN 1918

By

H. W. HAWTHORNE, Assistant Farm Economist
H. M. DIXON, Associate Farm Economist, and
FRANK MONTGOMERY, Assistant Farm Economist

CONTENTS

	Page		Page
Introduction	1	Farm Organization and Business Analysis	
Summary of Results	3	of Farms—continued.	
Area Studied	5	Farm Earnings	31
Utilization of the Land	7	Family Farms	38
Farm Organization and Business Analysis		Choice of Enterprises	43
of Farms	8	Diversity	46
Size of Farms	10	Factors Affecting Successful Operation of	
Crops Grown and Yields	11	These Farms	50
Receipts	21	Bearing of Farm Organization on Cost of	
Expenses	25	Producing Cotton	58
Capital	28	Appendix	72



WASHINGTON
GOVERNMENT PRINTING OFFICE
1922

UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 1036

Contribution from the Forest Service
WILLIAM B. GREELEY, Forester

Washington, D. C.

PROFESSIONAL PAPER

October 20, 1922

COAL-TAR AND WATER-GAS TAR
CREOSOTES: THEIR PROPERTIES
AND METHODS OF TESTING

By

ERNEST BATEMAN

Chemist in Forest Products

CONTENTS

	Page
Part I. Tars and the Production of Creosotes from Tar	3
Part II. Experimental Comparison of Authentic Specimens of Creosote	23
Part III. Properties of Creosotes	47
Part IV. Methods of Testing Creosotes and Official Specifications for Creosote	87
Appendix	106
Bibliography	112



UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 1037

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C. PROFESSIONAL PAPER August 19, 1922

**THE CONTROL OF SAP-STAIN, MOLD, AND
INCIPIENT DECAY IN GREEN WOOD
WITH SPECIAL REFERENCE
TO VEHICLE STOCK**

By

NATHANIEL O. HOWARD, Pathologist
Office of Investigations in Forest Pathology

(In cooperation with the Forest Products Laboratory of the United States Forest Service,
Madison, Wis.)

CONTENTS

	Page		Page
Introduction	1	Durability of Stained or Molded Wood .	17
Sap-Stain.	3	Losses Due to Sap-Stain or Mold. . . .	18
Other Fungous Organisms Causing Sur- face Discolorations in Green Timber .	12	Control Measures	21
Factors Which Favor the Growth of Sap- Stain and Mold Fungi.	14	Summary.	50
		Literature Cited	52



UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 1038

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.

March 20, 1922

PECAN ROSETTE

ITS HISTOLOGY, CYTOLOGY, AND RELATION
TO OTHER CHLOROTIC DISEASES

By

FREDERICK V. RAND

Pathologist, Laboratory of Plant Pathology

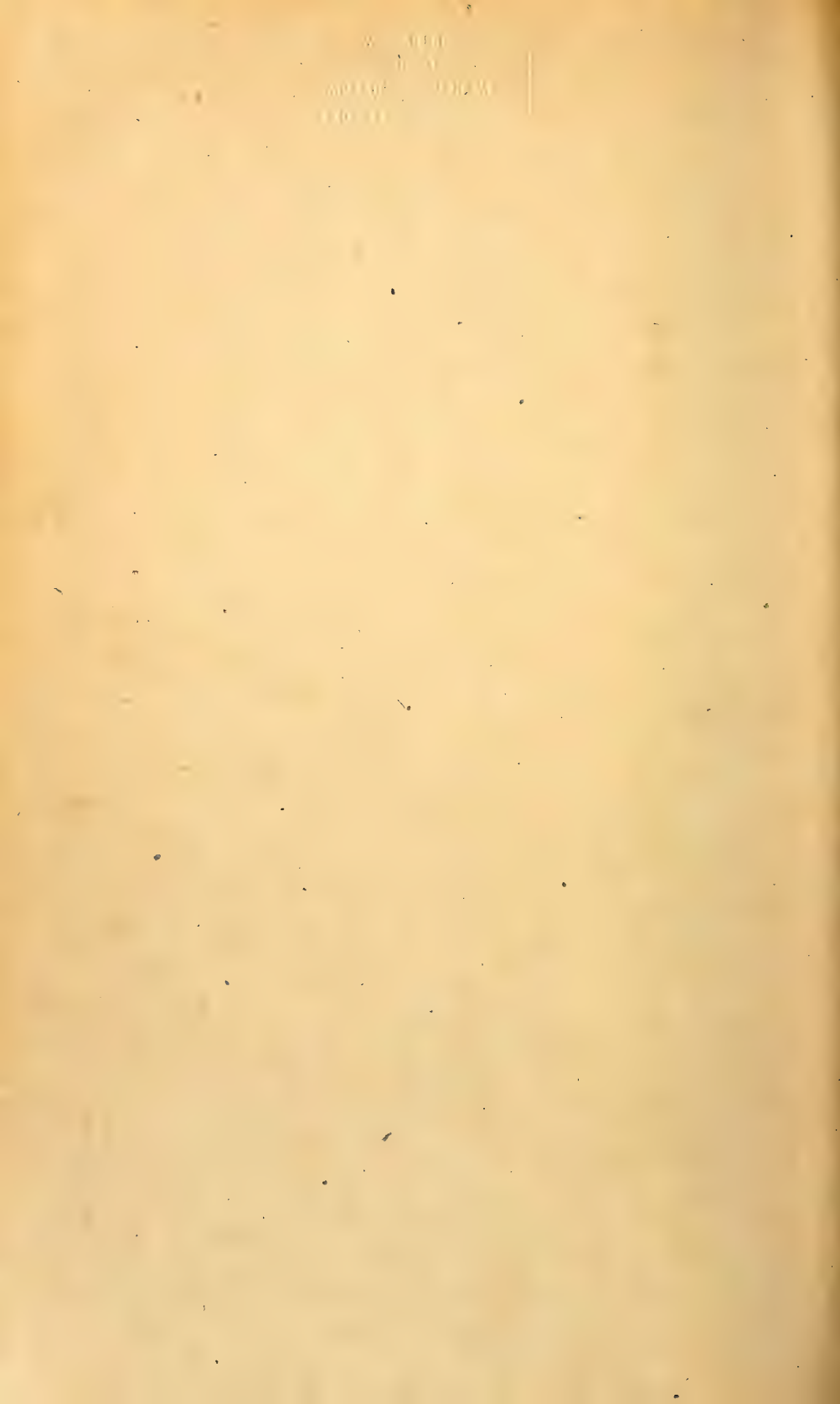
CONTENTS

	Page		Page
Types of Chlorotic Plant Diseases	1	Studies of Pecan Rosette—Continued.	
Chloroses Due to Soil or Atmospheric		Histological and Cytological Studies	19
Conditions	2	Subsidiary Experiments	30
Infectious Chloroses	6	Probable Nature of Pecan Rosette	31
Studies of Pecan Rosette	13	Summary	36
Results of Previous Work	13	Literature Cited	37
External Signs of Rosette	17		



WASHINGTON
GOVERNMENT PRINTING OFFICE

1922



UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 1041

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.



January 11, 1922

A STUDY OF SWEET-POTATO VARIETIES
WITH SPECIAL REFERENCE TO
THEIR CANNING QUALITY

By

C. A. MAGOON and C. W. CULPEPPER

Office of Horticultural and Pomological Investigations

CONTENTS

	Page
Introduction	1
Chemical Composition of Sweet Potatoes	3
Experimental Canning Tests	6
Discoloration	13
Heat Penetration and Sterilization	16
Consistency	16
Varieties and Strains of Sweet Potatoes Used in These Tests	23
Summary	30
Literature Cited	33



UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 1044

Contribution from the Bureau of Markets and Crop Estimates
H. C. TAYLOR, Chief

Washington, D. C.

April 19, 1922

SELF-SERVICE IN THE RETAILING
OF FOOD PRODUCTS

By F. E. CHAFFEE, formerly Investigator in City Marketing
and McFALL KERBEY, Assistant, Bureau of Markets

CONTENTS

	Page.
Introduction	1
Self-service	2
Advantages and Disadvantages of Self-service	4
Problems in Self-service	14
Handling Perishable Farm Products	35
Accounting	39
Summary of Investigations	49



WASHINGTON
GOVERNMENT PRINTING OFFICE

1922

A study of the principles of self-service, their application to the retail distribution of foodstuffs, and the results obtained through their application, necessitated a close cooperation between the Bureau of Markets and the operators of self-serve grocery stores. Almost without exception the retailers from whom information was requested evidenced a keen desire to cooperate with the bureau.

Special acknowledgment is due to the managing director of the Duffy-Powers Co., Rochester, N. Y., for his personal aid and his generosity in granting the bureau practically unlimited use of the self-serve grocery department of the company for investigational and experimental purposes.

Other stores and organizations cooperating with the Bureau of Markets in this study were: Hillman's, Chicago, Ill.; Liberty Market, Indianapolis, Ind.; The Groceteria, St. Paul, Minn.; Piggly-Wiggly, Memphis, Tenn.; L. S. Ayres & Co., Indianapolis, Ind.; Acme Stores Co., Los Angeles, Calif.; The Emporium, San Francisco, Calif.; Bay Cities Mercantile Co., Santa Monica, Calif.; Groceteria Stores Co., Seattle, Wash.; Gerard Grocery Co., Pomona, Calif.; U-Save Stores (Inc.), Cambridge, Mass.; and bureau of business research of the graduate school of business administration of Harvard University.

UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 1045

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.

March 18, 1922

THE SUNFLOWER AS A SILAGE CROP

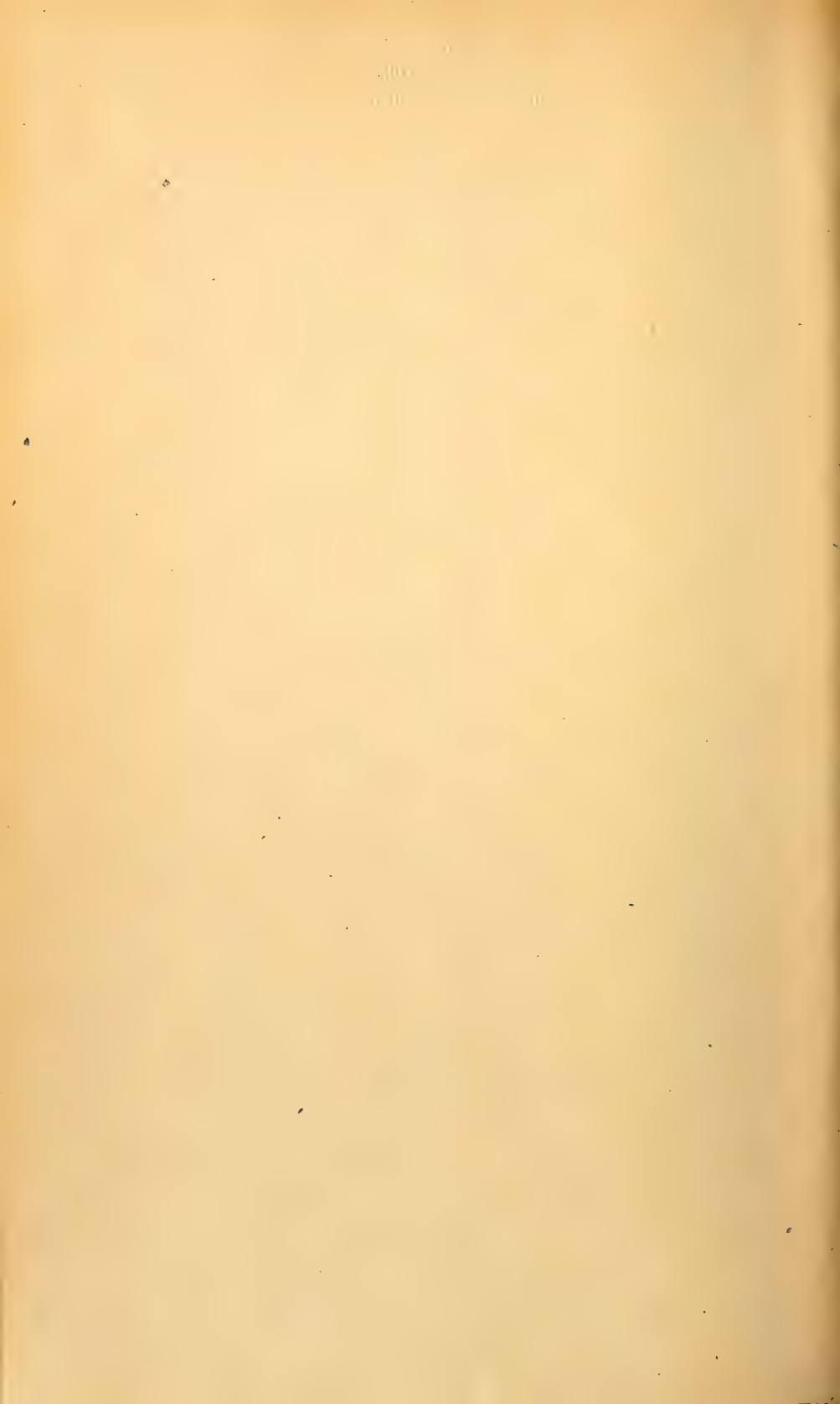
By

H. N. VINALL, Agronomist
Office of Forage-Crop Investigations

CONTENTS

	Page		Page
Early History of the Sunflower	1	Filling the Silo	15
Present Distribution	2	Yields of Silage	17
Cultivation in the United States	2	Feeding Value of Sunflower Silage	20
Areas Suited to the Production of		Composition and Digestibility	20
Sunflowers	4	Palatability	21
Value of Sunflowers in the Semiarid		Color, Texture, and Odor	23
Regions	5	Acidity of the Silage	23
Soil Relations and Effect on the Fol-		Results with Dairy Cattle	23
lowing Crop	7	Feeding Tests with Beef Cattle	26
Varieties	7	Use of Sunflower Silage in Feeding	
Growing Sunflowers for Silage	9	Sheep	27
Date of Seeding	10	Feeding Sunflower Silage to Hogs	29
Method and Rate of Seeding	10	Sunflowers as a Soiling Crop	29
Cultivation and Irrigation	11	Diseases of Sunflowers	30
Harvesting Methods	12	Insects Attacking Sunflowers	31
Time to Cut Sunflowers	13	Literature Cited	31





UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 1046

Contribution from the Bureau of Plant Industry, WM. A. TAYLOR, Chief,
in cooperation with the Kansas Agricultural Experiment Station

Washington, D. C.

May, 1922

RUST RESISTANCE
IN WINTER-WHEAT VARIETIES

By

LEO E. MELCHERS, Plant Pathologist, and JOHN H. PARKER,
in Charge of Crop Improvement, Kansas Agricultural Experiment
Station; Agents, Office of Cereal Investigations

CONTENTS

	Page
Scope of the Investigation	1
Review of the Literature	2
Nursery Experiments	4
Greenhouse Experiments	14
Comparison of Nursery and Greenhouse Results	23
Evidence of Specific Rust Resistance	24
Agronomic Value of Kanred Wheat	26
Summary	27
Literature Cited	30



WASHINGTON
GOVERNMENT PRINTING OFFICE
1922



UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 1049

Contribution from the Bureau of Biological Survey
E. W. NELSON, Chief

Washington, D. C.

March 14, 1922

GAME AS A NATIONAL RESOURCE

By

T. S. PALMER

Expert in Game Conservation

CONTENTS

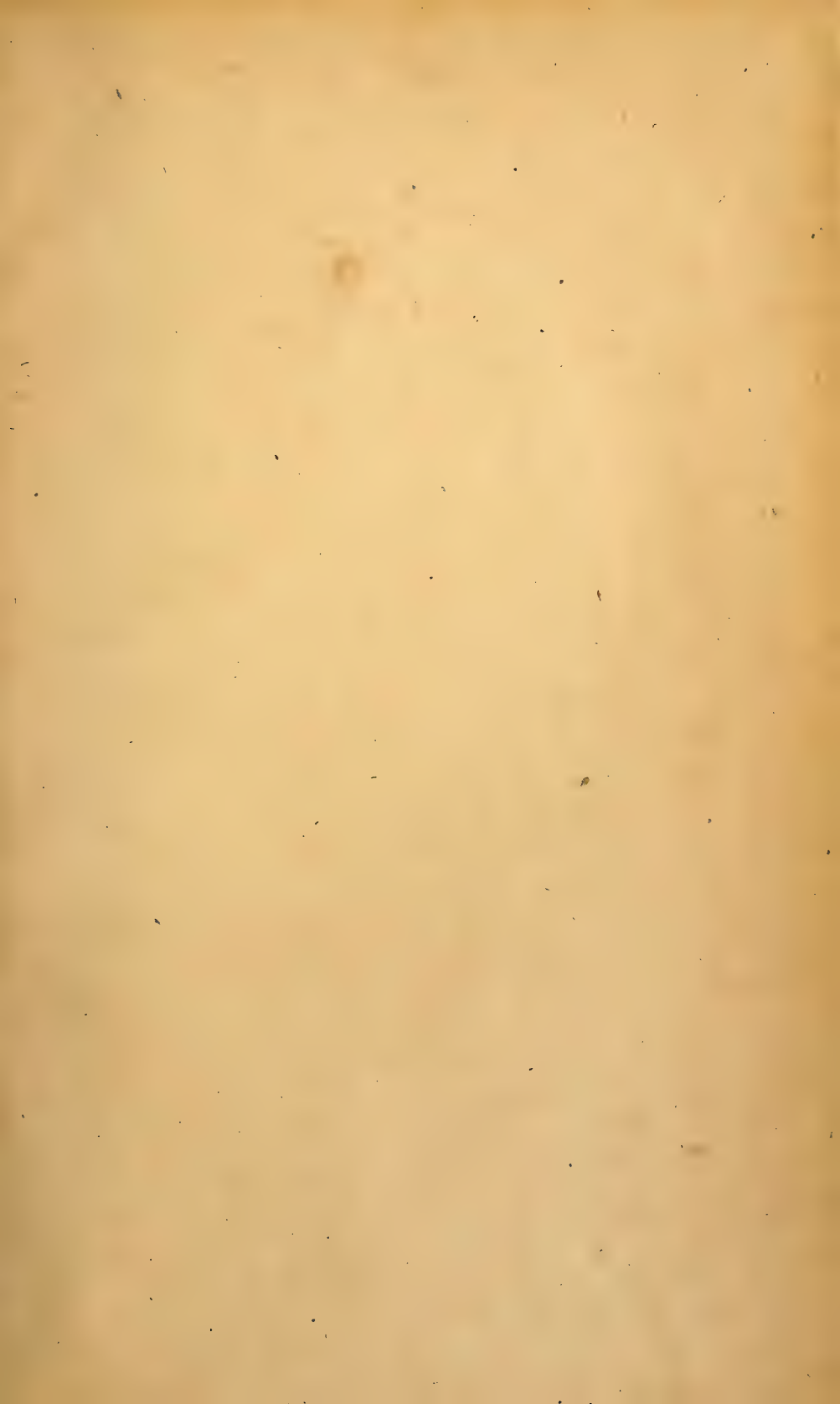
	Page
Importance of Game	1
Principal Kinds of Game in the United States	2
Value of Game to the Farmer	9
Value of Game from the Standpoint of Health	10
Returns from License Fees	11
Estimates of the Value of Game by State Officials	12
Limitations on Excessive Hunting	15
Records of Game Killed	18
Enumerations of Game	23
Methods of Increasing Game Resources	25
Cost of Maintaining Game	44
Suggestions for Making a Survey of Game	47

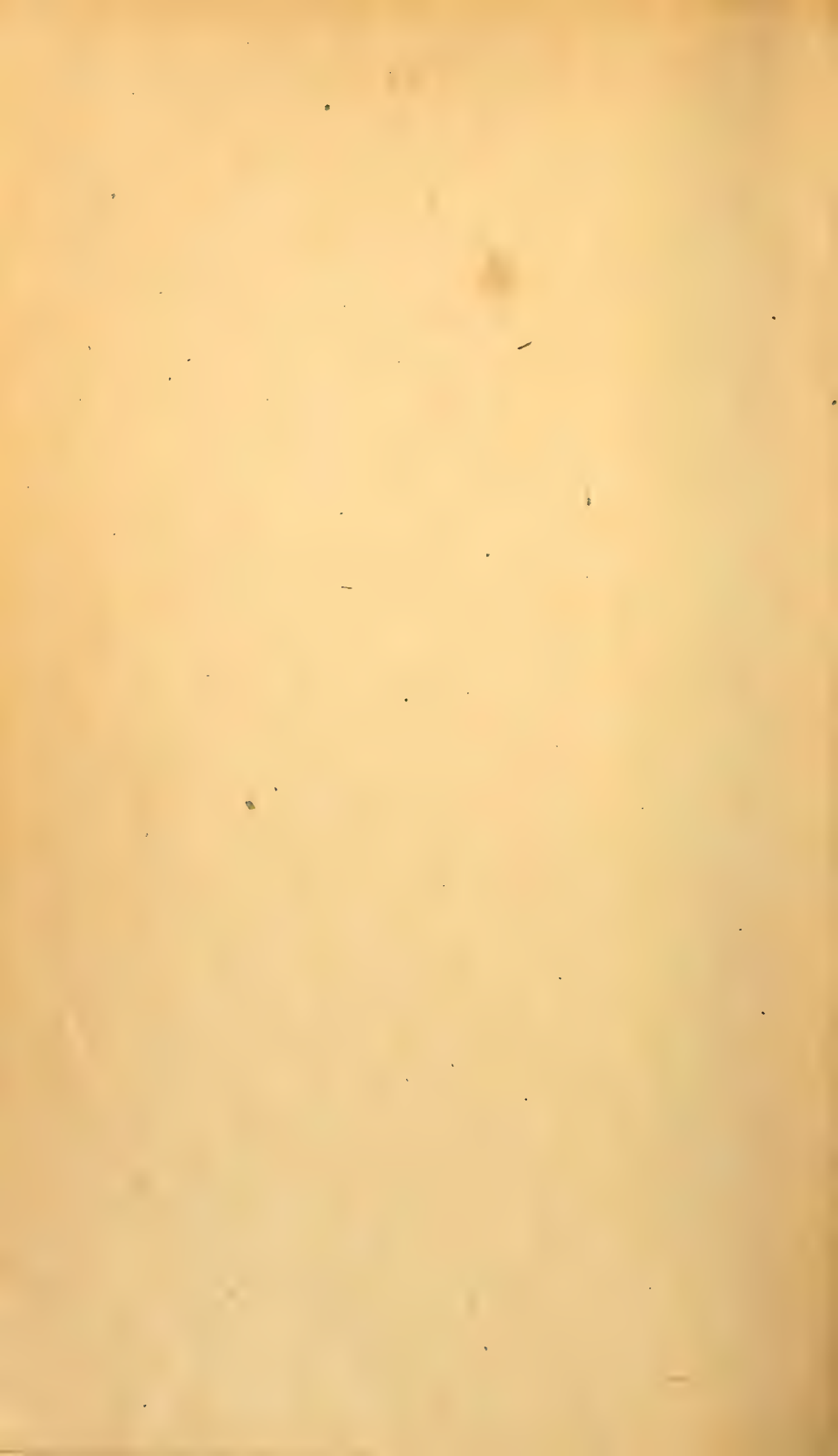


WASHINGTON
GOVERNMENT PRINTING OFFICE
1922

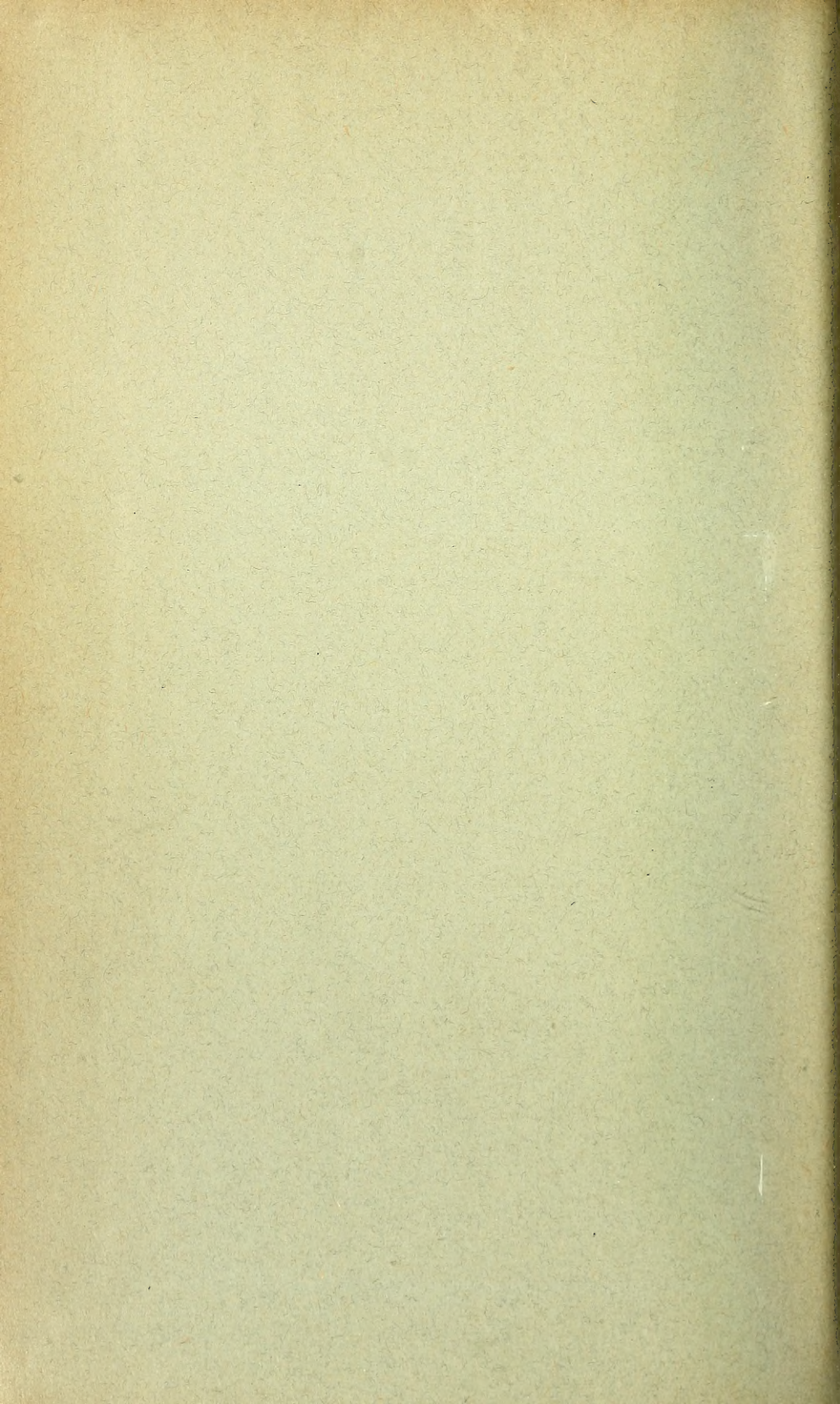
1000000

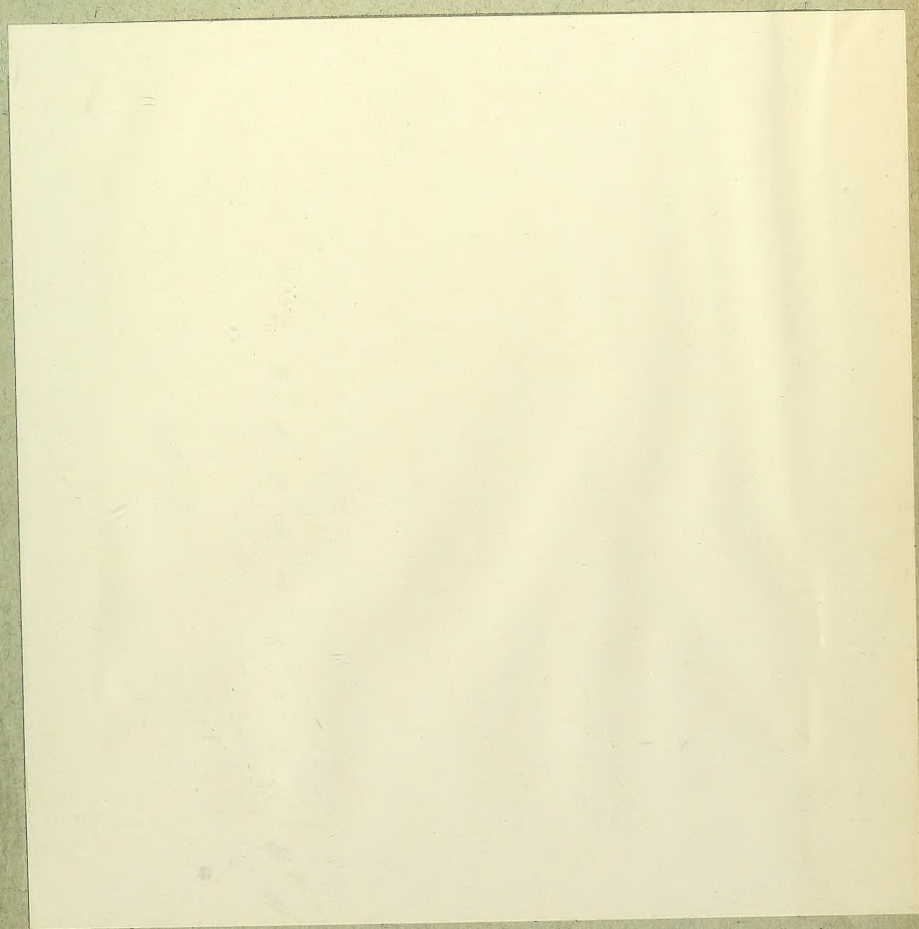
1000000











AMNH LIBRARY



100159666